PRINCIPLES
OF
WOOL COMBING

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PREFACE TO THE FIRST EDITION

In preparing this book it has been my chief object to arrange facts and statistics in such a way that the figures shall not be merely lists of dimensions and speeds, but that they shall help to explain the value of each working part, in the theory and practice of wool combing.

The most recent types of machinery are taken as illustrations; this is not to emphasise the special design which, for the moment, is considered nearest to perfection, but to show, by comparison with older machines, what are the main ends in view in each successive process, what are the root principles involved, and in what way the most modern machines surpass their predecessors.

In some types, so little alteration has been made for many years, that some people seem to consider that finality of design has been reached. If we can judge from the march of events in other industries nothing could be further from the truth, and it seems that, if radical improvements are still to be effected, the consideration of root principles will give the necessary impetus, so that improvements will not necessarily be variations of some existing type, which may in its own way be very nearly perfect.

Opinions in the trade differ so widely on many subjects that any attempt to give precise details for the working of special qualities would be simply courting contradiction. The figures here given have been specially obtained from the most reliable sources, and may safely be taken as examples, but it does not therefore follow that all of them would be considered correct by any

one practical man. They must be regarded rather as a means to an end than as an end in themselves.

To the student, statistics which convey no special idea are only confusing, for he may be brought up to use one type of card or comb for a certain quality, only to find when he gets a situation that good results are expected from similar material by entirely different methods. This book is an attempt to formulate lines of thought along which such a man may reason for himself. It is not intended for those who have no acquaintance with machinery. To describe a card or comb to persons who have never seen such a machine would require more illustrations and more description than can have place here. For similar reasons, the majority of illustrations are line *diagrams* only. Their simplicity may lay some of them open to the charge of incompleteness, because gearing and other parts which are less important have been omitted, in order that essential parts may be more easily seen.

It may be contended, with justice, that no attempt is made to enumerate many different makes of machines or to describe all the allied processes. There are few men well enough acquainted with all branches of the trade to do this, and I have preferred to leave unmentioned processes of which I have no personal knowledge, and only to touch briefly on details with which I have but slight acquaintance.

The variety of terms in use for the same materials or machines, in different branches of the trade, has made the selection of technical terms a very difficult matter. For instance, in the fine Botany trade "Slipe" means wool which has been removed from the skin by the lime process, the term "skin wool" being used when no lime has been used. In the long wool trade these two terms are used with exactly the opposite meaning.

Many similar instances might be quoted; and to

avoid increasing the confusion which already exists, I have adhered to the terms in use in the fine Botany trade, with which I am most familiar; and to avoid mistakes in doubtful cases I have tried to make my meaning clear in the text.

I am glad to acknowledge the courtesy with which I have been treated by every firm to whom I have applied for information.

Mr. W. Andrews kindly supplied the sales statistics contained in Chapter I.

Mr. F. H. Bentham not only sent the particulars of Noble comb circles, printed in Chapter X., but worked out for me the valuable data as to spacing, which appear with them for the first time.

Messrs. Hoyle & Preston sent me drawings and statistics of Lister combs, Chapter VIII.

Messrs. Samuel Law & Sons supplied particulars of card clothing, Chapter IV.

Messrs. J. & W. M'Naught allowed me to use a drawing of their washing machinery, Chapter II.

Messrs. John Petrie, Jun., Ltd., have placed a block of their drying machine and a drawing at my disposal.

To Messrs. Prince, Smith & Sons I am indebted for working drawings of their comb, and the photograph in Chapter XI.

Messrs. Taylor, Wordsworth & Co. have not only supplied particulars of preparing machinery and combs but they have checked some of my calculations, and lent three blocks and a photograph.

It was due to the kindness of Professor Beaumont, M.I.M.E., that I was able to make my carding tests on one of the machines at the Yorkshire College, and I have also to thank him for the offer of statistics and an illustration.

Professor Procter, F.I.C., has kindly corrected the

proofs of Chapter III., and given some of the information contained therein.

My thanks are also due in a special manner to Mr. John Brown, now of Morecambe, who worked with me for many years at Ashfield Mills, in Bradford. He has placed unreservedly at my disposal the whole of the valuable notes which he compiled from many years of practical experience, and much that is most interesting in the chapters dealing with the three combs is based on his observations.

PREFACE TO THE SECOND EDITION

For the new edition, this book has been thoroughly revised and considerably augmented. Details of several obsolete machines have been removed, and reference is made to new types of washing machinery. A whole chapter is inserted regarding the Heilmann Comb, which is now being worked more largely than ever before.

For particulars regarding the washing machinery, the writer is again indebted to Messrs. John Petrie Junior, Ltd., who supplied considerable information for the first edition.

The chapter regarding the Heilmann Comb contains many facts concerning the details of this interesting machine which it would have been impossible for any merely technical writer to collect and summarise. To Mr. Herbert Peel, of the firm of Messrs. Robinson and Peel, I am therefore indebted, not only for the opportunity of seeing Heilmann Combs at work and seeing them dismantled, but I am also indebted to him for explaining to me many of the intricate motions which are embodied in the machine, and, finally, for revising the proof of the chapter in question.

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CHAPTER I

WOOL

THE pressure of competition has necessitated the subdivision of the worsted industry into so many separate processes, and each of them is now treated so scientifically, that it is impossible for one man to master all the intricate technicalities of each process, and also to acquire the practical knowledge which only comes from years of experience. In order to secure the best results it is clearly desirable that certain men should become specialists in each of the different branches; and it must not be forgotten that an acquaintance with previous and after processes enables a man to treat every lot which passes through his department in the way best suited to its character, and with due regard to its final use and destination.

In certain trades it is well known that some classes of wool are absolutely fatal to the finish which is necessary on the cloth, although no one could detect the difference in the tops if the wools were judiciously blended before combing. On the other hand, there are wools of exceptional value to the spinner and manufacturer, which show very little sign of their qualities in the appearance of the top made from them.

Some years ago there were many firms in Bradford which were equipped to take the raw material through every process until it was made into cloth, and in firms

so constituted it was easy for a manufacturer to see that a certain class of goods was always made from the same class of wool. In these days, however, there are few firms left who adopt such a comprehensive method, and it is no uncommon thing for wool to be treated by four separate firms before it reaches the dyer. In most cases—

1. The wool is bought or imported and sorted by a topmaker.
2. Sent to a commission comber, who combs the wool for the topmaker and returns the top, noil, and waste to him.
3. The top is sold by the topmaker to a spinner, by whom it is blended with other tops and spun into yarn.
4. The yarn is sold by the spinner to a manufacturer and made into cloth.
5. The cloth is sold to a merchant.
6. It is usually delivered by the manufacturer to the dyer, who dyes it for the merchant.

Unfortunately, this extensive subdivision of the worsted trade makes it almost impossible for a manufacturer to be certain what class of wool his yarns are made from, and consequently, it is far too common a thing for one delivery of yarn to be woven, dyed, and passed as correct in quality and colour, whilst the next delivery may look exactly the same and make a satisfactory grey piece, but when dyed will not take the necessary shade or finish. This uncertainty is the greatest drawback to the system of subdivision which is now so general, and it lays a man open to complaints about faults in the finished article which may be due to the work of his predecessor, or *vice versa.*

Contrary to the principles of the law of England, which accounts a man innocent until he is proved to be guilty, trade usage now renders a man liable for defects

in goods which have passed through his hands unless he can prove that he is not responsible for them. As this view is very widely accepted, it is highly desirable that every man should have a theoretical (and, as far as possible, a practical) knowledge of processes which precede and follow his own.

For the present purpose wool may be divided into two divisions—the first including all the various classes suitable for the worsted trade; and the second, those used in the clothing or woollen trade.

It may be stated that, on the average, the worsted qualities are longer than those used for woollens; but the terms length and quality are always more or less relative, and many kinds of wool are used for Cheviot woollens which are longer than most of the wool which is combed and used for thick worsted Botany yarns. In Australian wools, the clip from a large flock nearly always contains wool suitable for both divisions, differing on account of the age of the sheep and the length of time the wool has been allowed to grow since the previous shearing. The same breeds of sheep living in different localities may also vary greatly as to the length and quality of the wool they produce; and the effect of suitable climate and feed go so far, that the wool of a cross-bred sheep steadily improves through succeeding seasons, if it be living under the most satisfactory conditions. If the first clip after it is full grown is only 46^s quality it may be difficult to distinguish the wool of the same sheep from a 56^s merino at the end of three or four years in good pasturage. Merino wools may improve from 58^s to 66^s quality in the same time. Considering these facts, it is clear that no hard-and-fast tabulation can be made of the countries which produce wool suitable for the woollen and worsted trades respectively; but a comparison of the nature of

the fibres in woollens and worsteds, of the mechanical structure of the two threads, and of the methods employed to augment their contrasting features, will show clearly what is essential in both classes of raw material.

Nature of Material.—In woollens the fibre is shorter and softer than in worsteds, and individual fibres should show great waviness, though the length of each wave should be very short. Each fibre should have many serrations and small scales,—waviness and serrations being very valuable factors in milling: small scales, breaking up the reflected light, give the dull or dead effect so characteristic of woollen cloths.

In worsted, the staple should be sound and of good uniform length combined with the greatest possible fineness. Waviness and serrations in the fibre are also of great value, but in worsted they are useful to enable the fewest possible number of fibres to adhere firmly together when twisted in the form of thread; or, in other words, they enable the greatest possible length of yarn to be spun from a given weight and quality of top. Large smooth scales are desirable, as they reflect the light and add to the bright appearance always associated with worsted fabrics.

Mechanical Structure of Yarns.—In woollens the fibres are arranged so that none lie straight, and all cross one another with the utmost frequence and irregularity, so as to produce the greatest diameter of yarn for a given weight. Spinning power is of quite secondary importance, as it is seldom desired to spin a given quality to the finest possible counts.

In build a worsted yarn differs in every respect from woollen. Theoretically, all the fibres in a thread should be as nearly parallel as possible, so that all the serra-

tions on each fibre may be in contact with those adjoining it, and the greatest possible tensile strength may be obtained from the smallest number of fibres. The parallel arrangement of the fibres also helps to reflect the light and adds to the natural brightness of the material.

The processes through which worsteds and woollens go are arranged to increase their different natural characteristics.

In the woollen process there is no gilling or combing to straighten the wool. Between the two carding machines the sliver is laid exactly across the feed-sheet to obtain more frequent crossing, and the way in which all doffers take the wool from the swift makes it necessary to strip the sliver from the doffer heel first, in a very curly and contracted condition.

Fine worsteds which are carded go through five gilling (or continuous combing) processes in addition to the combing proper; and low, bright worsteds, which are prepared instead of being carded, are gilled seven times before they reach the comb, and twice after they leave it. In addition to straightening and stretching the fibres whilst hot, the comb removes a large proportion of the short, curly fibres which form the "bottom" of a carding or top, all of which are left in the sliver in the woollen process to add to the bulkiness of the thread.

It will be seen from these broad comparisons that a necessity for waviness and serrations in the fibre is the only characteristic common to woollens and worsteds, and for a comber their wide essential differences may be summed up very briefly.

A woollen yarn must be as soft and bulky as possible, the natural tendency of the wool to mill being increased by the frequent crossing in the carding and the absence

of combing, whereby all the short wool present in the card is left in the spun thread.

The necessary qualities for a worsted are uniform length and soundness to insure good spinning power, fineness of hair to give softness, and straightness in the arrangement of the fibres in the yarn to assist in obtaining the bright, clear appearance which is typical of worsted cloths, and which is added to by the removal of the noil in combing.

Classification.—All the wool or hair which is used in the textile industries is derived from animals of the sheep tribe, though many of them differ very much in appearance from the sheep of this country or Australia.

The species *Ovis aries* is indigenous to Europe, and includes all the animals which are usually known as sheep.

Ovis Ammon includes the more goat-like animals of Thibet and South America, which produce mohair and alpaca.

Under *Ovis musimon* comes the camel and a small and very wild animal, the Vicuna, living in South America, which produces the finest known fibre of the nature of wool.

If the different types of each of the great classes is analysed many strange anomalies are apparent, and any classification must necessarily be open to great criticism; especially as it is often the case that one district produces wool of diverse types. Moreover, it is often impossible to tell where one class ends and another begins, so that the following list must only be taken as giving a rough idea of the nature and uses of wools from different localities:—

				Diameter
Ovis aries	United Kingdom	1. Wild Primitive	Highland, Welsh, Irish	$\frac{1}{500}$ to $\frac{1}{1000}$
		2. Forest or Mountain	Exmoor, Blackface, Cheviot, Herdwick	$\frac{1}{1200}$ to $\frac{1}{1500}$
		3. Ancient Upland	South Down, Norfolk Down, Somerset, Dorset	$\frac{1}{1000}$ to $\frac{1}{1200}$
		4. Long Wool	Lincoln	$\frac{1}{500}$ to $\frac{1}{700}$
			Leicester, Romney M., Cotswold	$\frac{1}{700}$ to $\frac{1}{1000}$
	Merino	Europe	Spain, Silesia, Saxony, Austria	$\frac{1}{2000}$
		Australia	Port Philip, Adelaide, Sydney, Queensland, Van, New Zealand	$\frac{1}{2000}$ to $\frac{1}{3300}$
		Africa	Cape	
		S. America	Buenos Ayres, Monte Video, Peruvian	
Ovis musimon		Thibet	Cashmere	
		S. America	Alpaca	
		Angora	Mohair	
Ovis ammon		Wild	Camel, Vicuna	$\frac{1}{4000}$

Class 1—*Wild or Primitive.*—Highland, Welsh, and Irish mountain sheep are so similar that they may be classed together. The sheep are not large, and as little attention is paid to their breeding or feeding, the fleeces are low and very irregular in quality, containing a great amount of kemp and coloured fibres. Some fleeces even show traces of the original hair with which the wool was covered when the animals were wild.

Used principally for carpet yarns and low Cheviot woollens, like Harris tweed. A very small proportion of the better flocks is good enough to mix with other good wools for combing.

Class 2—*Forest or Mountain.*—

A. Blackfaced or heath sheep produce wool more regular in quality, rather finer and with less kemp than Class 1, but they contain black hair, and the exposure to wild weather on the hills of Cumberland, Westmorland, and Yorkshire makes the wool hard and uneven.

B. Herdwick sheep live in the same districts as Class 1 and Class 2A, and are larger animals, with better wool, which is not close grown, but is freer from kemp and strong hair than 2A. The fleece weighs 3 to 4 lbs.

C. Exmoor sheep from Devonshire and Cornwall are small, with white faces, yielding a shorter wool than the above.

D. Cheviot sheep live in the hilly country in South Scotland and on the Border. They are one of the most valuable English breeds. The wool is usually fine, but grows so close as to produce a fleece equal in weight to those of much greater length. Prior to the introduction of Botany, it was largely used for worsteds as well as woollens, but is now mostly used for making the famous Cheviot woollens, its closeness and excellent milling properties making it particularly suitable for this trade.

Class 3—*Ancient Upland* sheep are smaller than Class 2; their wool is quite white, entirely free from black hairs. They are particularly suited to the chalk downs of the southern counties, and though they are found in Hampshire, Somerset, and Dorset, the most typical qualities are found best developed in the well-known breed of South Down in Sussex, which is the most important of all the English short-woolled sheep.

Class 4—*Long-woolled Sheep.*—

A. Lincoln sheep come from the Fen Districts of Cambridge, Norfolk, and Lincoln, and from the Wolds; they produce a fleece of 8 to 16 lbs. weight.

The wool is very long and strong, with comparatively few serrations and large smooth scales, which give to the wool a bright appearance. The original breed produced longer wool, and a heavier fleece than any other breed. The weight varied from 10 to 12 lbs., and the staples sometimes reached the extraordinary length of 36 ins. As in the case of many other English breeds, the pure Lincoln is now difficult to find, as it was found that when crossed with Leicester a slightly hardier and smaller sheep was produced which yielded as much wool as the Lincoln, of a quality as fine and silky as the Leicester. The great length of this wool made it so difficult to clear by the old carding or woollen process that hand-combing was first introduced to make a more satisfactory sliver from it, and it may therefore claim a share in the foundation of the whole worsted industry. Tops sometimes reach a length of 16 ins., 12 ins. being not unusual. Its brightness makes it suitable for worsted yarns up to 30^s counts, which are woven largely into braids and bright dress goods.

B. Romney Marsh, from South Kent and Cotswold, from Gloucester and the valley of the Severn, are large sheep, with wool very similar to Lincoln, but rather lower in quality. Like pure Lincoln, they are now practically extinct, as great advantages were obtained by crossing them with Leicester.

Irish lowland sheep strongly resemble the above.

C. The Leicester sheep is better known, and has been more widely used to cross with other breeds than any other sheep. Its wool is long and silky, and though it does not reach to the extreme length attained by some Lincolns, it is considerably finer, softer, and brighter. It is of great value for all qualities of worsted yarns up to 40^s counts, the appearance of the top being very bright and lustrous.

The primary purpose of this chapter is only to deal with wools now in use in the textile trades of this country,

and though the real merino from Spain can scarcely be said to come under this head at the present time, it played such an important part in the development of the fine worsted industry, that it cannot be omitted.

In Spain there were originally three breeds of sheep—the Chunah, the Stationary Merino, and the Migratory Merino; and it is from the last of the three that nearly all the merino sheep in the world are descended. Until the beginning of the eighteenth century the export of sheep from Spain was prohibited under penalty of death, but shortly after that time, in 1715, a number were sold to Sweden. Presumably the climate was too cold for them, for we hear nothing of them again. In 1765 a flock of 300 was sold to Saxony, with very far-reaching results, for they increased rapidly in numbers, the wool became finer and shorter; and from their descendants is obtained some of the finest wool in the world—very short, but justly celebrated for its softness and felting power.

About the same time sheep were sold from Spain to Austria, and in Silesia their descendants still thrive and produce some of the finest milling wool in the world; but it was the introduction of merino sheep into Australia that made possible the wonderful developments of the woollen and worsted industries of Yorkshire.

Australian Wool

Port Philip Merinos are descended from the original Spanish merino sheep imported into the colony, where climate and feed have suited them so well that those which have been most carefully bred now produce wool which combines length and soundness with greater fineness than that of any other country. The wool is very much waved and serrated.

Ten or fifteen years ago the longest and best of these wools were regularly spun to 130^s worsted counts and small quantities would be formed which would make $1/160^s$. That is to say, it was sometimes possible to make a yarn of which fifty-one miles weighed one pound.

Apparently it did not pay to maintain flocks at such a pitch of perfection, and of late years the quantity of extra-super wool has steadily diminished until at the present day such material is practically non-existent. There appear to be very few flocks which have maintained the spinning quality of their wool at the level which held good in 1900, but this fact seems also to be true of most parts of Australia. No other colony can produce wool to beat that which comes from Port Philip and it is still used for all classes of fine Cashmere and Italian cloths, and for the finest worsted coatings. The shorter wools and lambs are used for the best West of England super woollens, billiard cloths, etc.

Port Philip Cross-bred wool from the same colony is grown from the same merino sheep crossed with Leicesters. They yield a medium quality fleece from 40^s-54^s quality with a round, sound fibre and good spinning quality. It is combed for use in all classes of cross-bred worsted yarns up to 56^s, for which its bright, clear appearance makes it particularly suitable.

Port Philip Leicester sheep of pure breed are also grown, and they produce wool which, on account of the climate, is long and supple if less lustrous than that grown in the home country. The wool is nearly all prepared and combed. It is classed with the cross-breds and used for yarns from 30^s to 44^s, both single and twofold.

Sydney Merino is grown in the colony to the north of Port Philip, and being nearer to the equator the climate

is warmer and drier. It suits the sheep very well, but no flocks are quite equal to the best of those grown in Victoria, though in characteristics the wools resemble one another. It is used for almost all the same purposes as Victorian wool, though it does not spin quite so far in worsted yarns; and for the finest beavers and other woollens it is not quite equal in milling quality.

Sydney Crossbreds are in all respects similar to Victorian wool of the same quality, but they have not the reputation for giving quite such a good finish in the dyed cloth. They are used for the same purposes as Port Philip of equal quality.

Queensland Merino is grown in the most northerly colony in Australia, and being still nearer to the equator the temperature is higher, and the scarcer vegetation produces a wool with less nature, so that, although the quality and staple are often good, there is a larger amount of tender fibre; and a greater proportion of the wool is suitable for woollens.

The better flocks grown near to the Sydney frontier are useful for worsted yarns up to 70^s, but the bulk of the wool is more suitable for 60^s. A large quantity of the shorter wool is used for Saxony woollens and army cloths, as it is soft, and of fairly good milling quality.

Adelaide has a reputation for exceedingly sound merinos, the average quality being rather lower than in Victoria. The wool contains a good deal of yolk and sand in the fleece and it consequently sells for a relatively low figure in the grease. It is used in worsted for dress goods, weft yarns up to 60^s and 66^s counts, and is especially suitable for twofold worsted warp yarns. In woollens it is suitable for medium fancies.

Western Australia or Swan River.—The climate and feed in this district differ so widely from those of Vic-

toria that the merino sheep have not improved in anything like the same way, but the wool is bulky, sound, and dry, very much resembling the best Down wool of this country. It is used for qualities from 46^s to 56^s, and is also blended with other classes of wool for 60^s. It is very suitable for sound 2/48 warp yarns.

Van Wool from Tasmania.—The temperate climate of the island is well suited to the growth of wool, and produces excellent qualities, which are clean, of good length, round haired, and sound. The best flocks produce wool suitable for 64^s to 80^s worsted, and a large number of marks run to 70^s quality. They are useful for mixing with other good qualities for almost all classes of worsted yarns and cloths. The shorter sorts and lambs'-wool blend well with other good clothing wools for all classes of woollens except the very best West of England dress face cloths.

New Zealand has a climate in both islands which is so suitable for sheep that all classes of merino and cross-bred wools are grown with great success. The wool has a decided resemblance to Victorian, being sound, round haired, and soft, and the moisture gives it a suppleness which is valuable to the spinner. Until recently the burr plant was unknown in the colony, and the freedom from vegetable matter gave an additional value to the wool, but unfortunately some sheep imported from Australia carried some burr seed with them, and the plant has now taken root in the islands. The wools are suitable for almost all classes of merino and cross-bred worsted yarns, and, in a less degree, they are used for woollen yarns in place of good Australian marks, which they strongly resemble.

Cape and Natal produce merino wool which differs in several respects from that of Australia. The breed

of sheep has received less care, and though the wool is fine it is shorter and usually less sound, with fewer waves and serrations than a similar quality from Victoria or Sydney. The sheep live and thrive on the leaves of a small shrub, karoo, but the absence of grass leaves the ground very sandy, and as the sheep naturally lie down on it, the fleeces soon get very heavy and dirty. The price in the grease is consequently low, but, when washed, the colour is remarkably white. Both classes were formerly combed into short tops and spun to thick counts for weft and hosiery; but since the breed has been improved the longer marks make fairly good 60s tops, and they are frequently used to cheapen other blends of 60s and 64s quality, which are sold as Botany.

Buenos Ayres and Monte Video wools have earned for themselves a poor reputation—poorer, perhaps, than they deserve. The climate suits sheep well and the feed is good, but lack of attention to the sheep, and careless methods of classing and packing, make the wool of much less value than Australian of equal quality, especially as it is harder and much more burry than any other class.

Much of the wool which is taken from the skins of dead sheep by lime comes to this country as "slipe," and a large quantity of medium qualities comes on the skins and is taken off by various processes here. A large proportion of the medium quality wool treated at Mazamet is cleaned and has the burrs entirely removed by scraping before it is taken from the skin (by the sweating process). Wool so treated is very free to work, giving a very high tear and producing a top which, though hard, is often sound and of good length.

The best 60s wool is combed into tops in oil, but a large proportion, which is shorter, is combed on the Continent without oil and spun on mules into thick

counts (20^s to 40^s worsted) for the hosiery trade, for which it is very suitable, as the yarns are soft and bulky and come in at a low price. As both classes mill poorly they are only suitable for the lower classes in woollens, and for this purpose they are more used on the Continent than in this country.

Falkland Island Wool is almost identical with pure Cheviot. The Scottish emigrants who inhabit the islands took out with them some pure Cheviot sheep, and as the breed has been kept pure and the climate is temperate, the wool produced still strongly resembles the Scottish variety. It is suitable for all goods for which Cheviot can be used.

Supply.—In Messrs Helmuth Schwartze & Co.'s report for 1902 they divide all the wool sold in London into three classes—viz., greasy, washed fleece, and scoured and slipe.

In the year 1869 there were sold		In 1902 the figures were
158,000	Bales Greasy.	681,500
266,000	,, Washed fleece.	2,500
114,000	,, Scoured and Slipe.	314,000
538,000	,, total.	998,000
15,000	of which were Crossbred.	477,000

These figures are very instructive. They show—

1. The total supply has nearly doubled in twenty-three years.
2. The total supply of crossbred has increased thirty-fold in twenty-three years, or from 3 per cent. to 47 per cent.
3. The washed fleece has practically ceased to exist as a class, and the quantity is divided between the scoured and greasy now coming to London. This is much to be regretted, as the wool had many good qualities. The growers hoped that by careful washing whilst

the wool was on the sheep, they would not only improve the style of the wool, but that they would also save cost of transit sufficient to pay for the washing. Unfortunately, prices in London did not warrant this theory, and the supply of this excellent type of wool has steadily decreased in consequence.

4. As pointed out in the next chapter, scoured wools have their disadvantages, but the saving in freight is so great when they come from certain localities that it pays the grower to put down scouring plant on his station to reduce this cost of carriage.

The saving effected by scouring looks very small when estimated by the pound, but on the great weights shipped from some stations the amount rises to a very substantial figure.

Ten years ago greasy wool yielding 50 per cent. of top and noil was carried from Melbourne to London by steamer for $\frac{3}{8}$d. per lb., or $\frac{1}{8}$d. per lb. less than scoured, because the greasy bales are much heavier, and a steamer can therefore carry more tons. Scoured wool yielding 75 per cent. or 80 per cent. was charged $\frac{1}{2}$d. per lb. Rates by sailing-ship were usually $\frac{1}{16}$th less. This means that greasy wool yielding 50 per cent. costing 10d. in the colony, would cost 10$\frac{3}{8}$d. per lb. in grease in London, or 20$\frac{3}{4}$d. per lb. clean in London.

The same wool after scouring at $\frac{1}{8}$d. per lb. $=10\frac{1}{8}$d. in Victoria.

10$\frac{1}{8}$d. + 25 per cent. loss in scouring $=15\frac{3}{8}$d. for wool of 75 per cent. yield.

15$\frac{3}{8}$d. + $\frac{1}{2}$d. carriage $=15\frac{7}{8}$d. for wool of 75 per cent. yield in London.

15$\frac{7}{8}$d. at 75 per cent. $=21\frac{3}{16}$d. per lb. clean wool in London.

Speaking of stations near the coast, it shows how

cheaply the scouring must be done, if it is to be of any advantage to the seller. To spend $\frac{1}{4}$d. per lb. and only reduce the loss from 50 to 75 per cent. would mean a dead loss to the grower. Cost of scouring must be reduced to $\frac{1}{8}$d. and yield improved from 50 per cent. to 80 per cent. before the cost in London is relatively equal to wool shipped in the grease.

These figures are now, of course, quite out of date, but the principles which underline them are just as important as ever.

But there is another item which never enters into the calculations of importers in this country—*i.e.*, the cost of transport from far inland stations in Australia to the coast. Where wool is sent down any river in barges this cost is only trifling, but from some of the Queensland stations the wool travels many hundreds of miles by bullock waggons, and it is in this case that the saving is the greatest. Climatic variations also affect the calculations. Prior to the great drought many marks grown within reach of the great Darling river were never scoured, but when the absence of rain made the river unnavigable the wool had to be sent by waggon, and the marks were scoured to make the transport less costly. In some cases the wool from these districts is very heavy in grease, yielding only about 33 per cent. of clean wool. After scouring they yield over 90 per cent., which means that the gross weight was reduced nearly 60 per cent., and a great saving thereby effected even before the wool left the colony.

For detailed information as to the various breeds of sheep and the inherent peculiarities of their wool, readers are referred to Dr. Bowman's exhaustive work on "The Wool Fibre."

CHAPTER II

WASHING

THE classing, sorting, blending, and packing of wool belong so essentially to the topmaker that it is not proposed to touch upon them here, and the only process previous to washing which concerns the comber is that of " willying," opening, or shaking.

Willying.—On this question experts differ diametrically: some contend that any process of the kind tends to break the staple and also to allow the wool to felt in washing; others say with equal truth that the shaking of locks and fleeces loosens the sand, and in the case of blends of scoureds and greasy, it mixes the two so well that each is in the best condition to affect the other. In any case, it opens them so that they are more easily permeated by the soap and water, and may therefore be washed at less expense.

Very long wools are certainly liable to breakage, and are therefore least suitable for willying, but beating or shaking must always loosen the solid matter in heavy, sandy, or limed wools, and a process which could effect this result without breakage would clearly be an advantage.

To put matted wool into a tooth-willy such as was once in vogue would clearly do it harm; and allowing that all wools must be slightly shortened in the process, it is for the user to decide whether the saving in soap and extra lightness after washing will compensate for any slight breakage there may be. It must be remembered that there is sure to be some slight breakage in

the carding, and it is doubtful whether there is more damage done to wool which is willyed and then carded than to matted wool which is carded only. As in many other cases, it is impossible to say definitely, and different qualities must therefore be judged upon their merits.

The *best greasy and washed* fleece wools do not need any opening process: they are not matted, and can be washed without undue expense.

Heavy sandy greasy wools may have so much sand removed that they are distinctly easier to wash, and if carefully treated they should be no worse for willying.

Scoureds are often so felted that they must have some fibres broken in willying. This would happen more or less in the carding in any case, but after washing the fibres would separate more easily than before that process.

Blends of scoured and greasy will go to the bowls much more uniformly mixed if they be willyed prior to washing, and there is no reason that they should be materially damaged in the process.

Skin Wools are so free and clean that they need opening less than any other class, but for that reason they are very unlikely to be injured in the process.

It is for Slipes that the willy is most useful. If properly adjusted the breakage of fibre should be very trifling, and it should remove so much of the lime, dust, and lumps that the cost of soap in the washing would be very greatly reduced, because, and as shown in Chapter III., each pound of lime removed will save nearly 15 lbs. of soap.

At one time a willy was understood to mean a swift covered with 20 rows of 2-inch teeth set 2 inches apart, revolving at 300 revolutions per minute, as near as

possible to two feed-rollers which were closely covered with curved teeth. The wool was held firmly by these rollers, and as it was torn through them by the pins of the swift it was natural that breakage resulted.

If a machine be constructed with beaters only, or with teeth on only one roller, the result will be very different.

A machine (Fig. 1) which has given very good results for slipes was made with fluted iron feed-rollers, 4-inch diameter (B), working under no pressure except their own weight; the swift (C) carried 8 rows of 1-inch

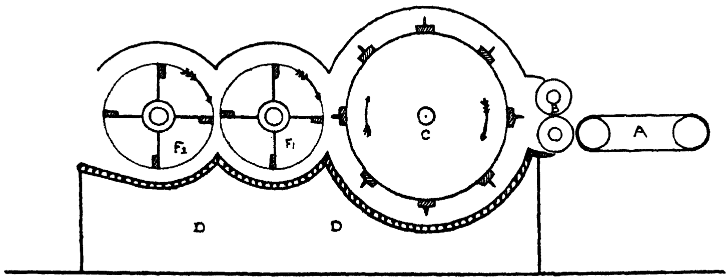


FIG. 1.—WILLY.

round pegs and ran at about 120 revolutions; next came an 18-inch fan running at 250 revolutions (F1), with a second fan (F2) running 300 to clear it. This machine opened the wool most efficiently, and the absence of pins on the feed-rollers prevented any breakage of consequence, whilst the centrifugal motion imparted to the wool drove the sand and dust through the grids into the dust-box (DD).

The shape of the grids was arranged to carry the wool up until it met the down-coming blade of the fan F1; here it was violently shaken without being torn, and on the way past F2 it parted with more dust before it finally left the machine.

With a fan fitted to the dust-chamber, a strong down

draught sucked the dust through the grids, but it also sucked out so much loose fibre that it was found better to allow the sand to fall by gravity and by centrifugal force, and not to apply pneumatic suction.

Another machine was made with four fans or beaters in a row, rotating above grids and a dust-chamber exhausted by a fan. For free but dusty wools this was very efficacious, as the wool was met by the down-coming blades at four consecutive points, as in Fig. 1; but wools like scoureds, which require partial opening, would come out too little affected to make the process valuable.

To secure the best results in washing the wool should not be packed or boxed but should go to the bowls as light and open as possible; if possible, the willy should stand on the floor above the washhouse, that the wool may slide down through bins or shoots to a place near the feed-sheet of the first washing bowl.

Wool Washing.—There are few things more detrimental to the true interests of the trade than is the very common idea that the *one* object of washing is to get wool "a good colour." It may, in fact, be laid down as an axiom that washing should only mean the removal of those impurities which prevent the wool giving the very best results in every after process through which it is destined to pass, with special regard to the dyeing and finishing.

Wool contains many necessary constituents which can be altered in their character and partially removed by severe washing, and if these be once extracted by excessive heat or strong reagents the wool not only loses unnecessary weight but it also loses some of its original properties, which can never be imparted to it again. The sub-division of the trade, and the consequent position of tops as a standard article of com-

merce on the market, have tended largely to this end, because a white top is always more saleable according to the standard of value which is at present accepted. It is true that many users are well aware that a vivid white (such as is obtained by the addition of any blue colouring-matter) is not of the slightest advantage in the finished article, if we except a few very special trades; and the spinner who combs for himself will not strive so hard to get his tops white as will the top-maker and the commission comber, who rely more for their success on the attractive appearance of the tops they produce. And if the accurate estimation of the value of tops were better understood, it is probable that the demand for an artificial white would be quickly allowed to decline.

The washer must class wool under at least five different heads—viz., greasy, fleece-washed, scoured, skin, and slipe—the term "skin" being here used to denote wool removed from the skins of slaughtered sheep by means of a sweating or similar process, "slipe" being taken to mean wool removed from skins by lime. In the bowls each class should receive a different treatment, but in practice the different sorts are very often blended prior to washing, with the idea that the better classes will help the poorer; and this quite irrespective of the fact that the lime and other matter to be found in slipes may do injury to the greasy, which is out of all proportion to the improvement that the slipe itself may derive from the combination.

To lay down rules on such a matter is impossible. The topmaker has strong inducements to blend many kinds of wool in one pile, and it is often done without the slightest detrimental effect in the washing; but the old proverb still holds good that "a silken purse cannot be made out of a sow's ear," and wools which have

once been really injured by the method of their removal from the skin can never be made to take a finish equal to the perfect greasy fibre. To be dogmatic on this subject would only be to show ignorance of facts, for a long and varied experience is the only means of obtaining the knowledge requisite to assess the relative advantages and disadvantages of each individual case; but a consideration of the peculiarities of the various classes may be of assistance to the blender as well as to the washer.

1. *Washed Fleece.*—Broadly speaking, it may be said that the wool washed on the sheep's back (it is sometimes done with warm water) prior to clipping is the best type imported and, at the same time, the easiest to treat properly in the washing. It contains all the yolk, with very little extraneous grease or sand, and as it can be got to the best attainable colour without alkali, with mild soap and suds at low temperatures, it reaches the top in the best condition to resist the severe treatment which all wool goods go through in finishing.

By careful washing the growers hoped to save cost of transit and at the same time improve the style of the wool; but, unfortunately, extra cost of washing was not made up to them by the reduction in freight or the extra market price obtained in London, and, consequently, this excellent type of wool is only seen in very small quantities.

2. *Greasy Wool.*—In addition to the original supply of greasy wool, almost all the best flocks which used to come to this country as washed fleece now come in the grease, so that the total quantity offered is now very large, being about 680,000 bales, or 70 per cent. of the total number sold in London in a year.

It reaches the user just as it is shorn from the living

sheep, and the fleeces therefore contain all the natural secretions which are present on the outside of the fibres during life, as well as the whole of the yolk or suint within the individual fibres, and all the dust, sand, and earth which have adhered to the fleece during life.

The surplus lubricants keep the wool in the best possible condition during transit, and if the dirt and extraneous grease are removed in such a way that none of the internal constituents of the fibre are extracted in the process, the wool will reach the top with the maximum amount of suppleness and nature. To attain this object the temperature of the water and the amounts of soap and alkali must be kept as low as possible during washing. To avoid the use of strong reagents plenty of water is necessary. Bowls 43 feet long, holding as much as 1,500 gallons, have been found to answer very well. Where large lots of greasy are washed alone the suds from the lowest bowl extract such a large proportion of suint that some firms treat the liquor separately and recover from it considerable quantities of oil and potash. Where there are such installations different methods are adopted to get the greatest amount of wool grease in the smallest possible quantity of water. The most usual method is a series of hoppers or tanks with perforated bottoms, so arranged on wheels and lines that they can be run in turns over a tank, the water from which is pumped up and allowed to fall in a heavy rain on to wool which is tightly packed into them. After about twenty minutes of this treatment almost all the grease and a fair proportion of the dirt have been extracted without the use of soap, alkali, or heat. The hopper is run away to the first bowl, and the wool cannot only be more easily washed, but there will be less soap, alkali, and heat applied, and the finished article will consequently handle better.

No rule or figures can possibly be given for the washing of this or any other class of material, for hardly any two marks require identically the same treatment, and every blend must therefore be given just as much soap as necessary, and no more carbonate of soda (or carbonate of potash) than will keep the suds nicely alkaline.

On page 31 a table is given showing the relative amounts of soap and alkali used for standard wools of four types, but the figures must only be taken as a rough indication of the quantities requisite for each kind.

Scoured Wool is fleece wool clipped in the colony, but scoured there prior to packing, and it varies very greatly in its yield. The whitest and lightest qualities have already been washed so thoroughly that almost all sand and grease have been removed, and the washing prior to carding serves rather to revivify the wool than to remove impurities, and good soap alone in water at 115° is all that is necessary for the purpose. Blended with greasy of equivalent quality this sort washes well, and will probably be improved in handle without detracting in any way from the quality of the greasy. The only disadvantage in using it arises from the fact that on some stations sufficient care is not taken as to the temperature of the water and the nature of the reagents used in scouring, so that not only the external grease and dirt have been removed but part of the suint has gone with them, and the fibre when it reaches the top consequently lacks the softness and suppleness of a pure greasy. The heavier scoureds are less liable to this defect, but as they contain more sand as well as more yolk and gum, they take a good deal more washing, and some of them require the addition of a considerable amount of alkali as well as soap to the

bowls. For most trades they can be blended with advantage with greasy, because the reduction in cost of transport makes them cheaper per pound when combed; but at the same time it is generally admitted that a pure greasy produces the best top for spinning, and one which gives a superior finish in many kinds of cloth.

Skin Wools.—Wool which has been removed from the skin by any other than the lime process is almost always partially cleansed, and as the grease and dirt are removed whilst the wool is still on the skin no felting or matting of the fibre occurs, and the wool reaches the user in a very free and open condition. That which is pulled in this country varies greatly in yield, but as a rule contains more of its original fats than the cleaner wools which come from France, many of which are so free from sand, earth, and grease and vegetable matter, that they yield well over 90 per cent. of clean wool. Such wools require so little agitation in the washing that they go to the carding-machine in perfect condition, and make a carding so free from knots and short wool that they often tear more than 20 to 1 in the comb. Unfortunately, the method by which they are cleansed and removed from the skin leaves them very dry, because some proportion of the suint which should remain within the walls of the fibre is removed, together with the external grease. The absence of this natural lubricant leaves the fibre dry and wanting in suppleness, and in treating such wools the main object of the washer should be to replace this loss by some other natural or artificial matter of a suitable nature. If these dry skin wools are blended with greasy prior to washing, the excess of natural fats in the one will often be absorbed to some extent by the other, but fibre once robbed of its yolk can never be

made "as good as new." A blend of equal quantities of greasy and skin wool will generally yield a top nearer in handle to the skin wool than to the greasy; in other words, the greasy will lose more than the skin wool gains.

If the skin wool be treated alone, the application in the bowls of a good neutral or superfatted soap, in excess of the quantity actually required for cleaning the wool, will leave it in the best possible condition for carding, if it is also treated with a suitable quantity of good oil. It is difficult to say exactly what office the soap fills, whether some of its fat is actually absorbed by the fibre, or whether it leaves the wool in such a condition that the oil can permeate to the very core of the spindle-shaped cells within the fibre.

Experiment shows that after the most suitable treatment, all the oil which is applied in the back-washing will not appear in a test for oil taken in the usual way; or, in other words, oil properly applied to skin wool will not all come out again in a simple washing process, with water and soap at 120° or under.

Slipe Wools.—Those who have to treat limed wools know what an enormous amount of soap it takes to "get them through the rollers." The lime really decomposes either the soda or potash soap which is used, forming from them harmful compounds, because the lime salts have greater affinity for the acid fats than has the soda or the potash contained in the soap.

As lime is in itself an alkali, the addition of any other alkali is of little or no use. The lime must be neutralised before soap is applied to the wool, and this can only be done perfectly by the use of acid. To many practical men this sounds a startling suggestion, but if a reagent be selected which will combine with the lime to form a non-injurious resultant compound, and if it be added

to the steeping water in such quantities that acid is never present in excess of the lime in the bowl, the wool need not suffer in the slightest from this treatment.

Almost any acid will decompose the lime, but some acids are much more injurious to wool than others, and some of them combine with lime in such a way as to produce salts not easily soluble in water or deleterious in their effect upon wool. Sulphuric acid and hydrochloric are cheap because they are very powerful, but their salts in combination with lime are not so easy to deal with as those of sulphurous acid, which is found for many reasons to be very satisfactory. In combination with lime it readily forms a salt which is so soluble that when squeezed the partially cleansed wool emerges from the rollers almost free from lime, and not excessively acidified. Anyone who has squeezed wool after immersion in water containing no soap will, of course, understand that the rollers must be very lightly weighted for this purpose, or the wool will be badly cut in going through them; but sufficient weight may be used to squeeze out a very large part of the acid solution. Of course, no soap must be applied in any process where acid is present or it will at once be separated into its original constituents, and the oil will float free on the surface of the water. Before soap is applied the acid must be entirely neutralised; the best method would be to pass the wool through pure warm water and then through a further bath of carbonate of soda, completing the washing process in two bowls of soap and water in the way suggested for the treatment of skin wool.

If this system were adopted for bulk lots, it would need a machine with five long bowls, but in places where occasional lots have to be dealt with a three-bowl set might be arranged—the first bowl containing the acid bath, the second bowl containing the warm water, and the third an alkaline bath kept continually replenished to

entirely neutralise the acid. When sufficient wool had been put through, the acid would be run off, the bowls made up with suds as usual, and the wool put through again in the usual way.

There are wools on the market which contain as much as 8 per cent. of lime, or 19·2 lbs. in every pack, which if present as calcium would destroy 288 lbs. of soap if treated with soap alone. A sticky lime soap would also be formed which would settle on the fibre and make it impossible to cleanse the wool thoroughly. By the other method it would require about 40 lbs. sulphurous acid to convert the lime into a harmless soluble salt, and say 5 lbs. of carbonate of soda to remove all trace of acid. The wool would be almost clean when it came from the carbonate bath, and it would require only a very small amount of soap to finish the washing and produce the best possible result. If a special set of five bowls were used the cost of wages would be equal in both cases, but as most combers would have to treat the wool twice in some existing set, we may reckon double wages, and still have a great saving as well as far better work.

Cases might occur in which blends of slipe and scoured, or even slipe with a small proportion of greasy, might be treated in the same way, but great judgment would be required, and the advantages would not be so clearly defined; but if a topmaker wished to blend a very limy lot of slipe with scoured or greasy, it would certainly pay the comber to treat all the slipe with acid and carbonate before blending, because the lime would combine with the wool fat as well as the fats in the soap and produce a proportionate quantity of the sticky and insoluble lime soap.

Suds.—When making up a set of new suds it is usual to run off the sud from the first or bottom bowl, which

contains most of the sand and dirt, and blow the sud from the second bowl into the first, where a little extra soap and alkali are added to it. The sud in the third bowl is practically clean, and is blown by a steam jet into bowl No. 2 and made up to the requisite strength, and an entirely new sud is always made in the last bowl. If allowance were not made for this fact the table would show a very high proportion of soap in bowl 3. As a matter of fact, much more soap is put into the last bowl than is neutralised by the comparatively clean wool which passes through it, and the sud possesses a great deal of scouring power when passed down to the bowl below it. But it is essential to have the top sud very clean if a specially good colour is required in the wool.

In the subsequent chapter some idea is given of the impurities contained in water, of their effect on the wool, the soap, and the alkali used in washing, and throughout the remainder of this book "water" may always be taken to mean water of 5° or less of hardness and free from any impurities injurious to wool.

It is generally admitted that the steeping process as used in the old-fashioned hand bowls was very satisfactory, for the yolk and dirt were thoroughly softened before the wool was touched by the fork, and a very large proportion of sand fell out in the small tank. To compensate for the absence of steeping, the first bowl of a machine washer is now made longer than the others, and the wool should move through it as slowly as possible, if it is to reach the first squeeze with the yolk and other impurities thoroughly softened.

In almost all the early machines rakes were used to move the wool forward through the stationary sud, to open it, and deliver it into the nip of the roller in such a condition that the dirt might be easily squeezed out.

TABLE showing relative amounts of soap and alkali and temperature, for wools washed in ten hours.—

		Greasy.	Scoured.	Skin.	Slipe.
	Yield	50 %	75%	80%	60%
	Packs washed	25	15	$12\frac{1}{2}$	17
	Clean wool	10	10	10	10
First Bowl 33 ft. long	Heat	120°	120°	120°	125°
	Alkali	40 lbs.	46 lbs.	50 lbs.	80 lbs.
	Soap	110 ,,	110 ,,	90 ,,	220 ,,
Second Bowl 27 ft. long	Heat	115°	120°	120°	125°
	Alkali	—	—	20 lbs.	40 lbs.
	Soap	50 lbs.	80 lbs.	70 ,,	160 ,,
Third Bowl 21 feet long	Heat	115°	115°	120°	125°
	Alkali	—	—	—	—
	Soap	40 lbs.	50 lbs.	60 lbs.	70 lbs.
Fourth Bowl 15 ft. long	Heat	110°	110°	120°	120°
	Alkali	—	—	—	—
	Soap	30 lbs.	40 lbs.	40 lbs.	50 lbs.
	Total Alkali	40 lbs.	46 lbs.	70 lbs.	120 lbs.
	Total Soap	230 ,,	280 ,,	260 ,,	500 ,,
	Alkali per pk.	2 lbs.	$3\frac{1}{2}$ lbs.	$5\frac{3}{5}$ lbs.	7 lbs.
	Soap ,,	$11\frac{1}{2}$,,	21 ,,	21 ,,	30 ,,

The rollers of a hand bowl usually stood at some height above the sud, and as the wool was lifted to them most of the water ran back into the bowl, leaving the wool in a sodden and relatively compact mass on the feed-apron. In this respect the machine bowl has a

very great advantage, because in the best types of washer the wool is practically floated into the nip of the rollers. To see the advantage of this treatment it is only necessary to try a very simple experiment. If a staple of wool (Fig. 2) be thoroughly saturated and suspended in water, every fibre will at once separate itself from its neighbour, and if it go to the squeeze in this condition,

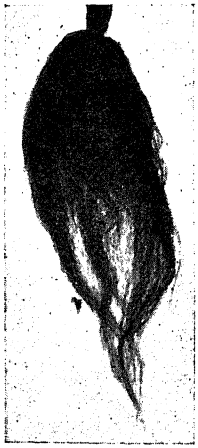


FIG. 2.

FIG. 3.

any sand or dirt can very easily get away. If the same staple be lifted from the water (Fig. 3) without being squeezed in any way, it will be seen to shrink in bulk, so that the fibres all touch one another. In the hand machine the wool reaches the rollers in the latter condition, and the dirt is often squeezed into the fibre, instead of being squeezed out into the water as it should be.

The machine which was most perfectly adapted to squeeze the wool whilst it was quite submerged was made by Messrs. Jefferson Bros. It had one brass roller B (Fig. 4), which was quite under water, and

another half immersed, with a third roller A, covered with wool-lapping, pressing against both of them. The wool actually floated right into the nip, and after being squeezed between A and B, passed again into the sud between the three rollers, only to be squeezed a second time between A and C and delivered on to an apron nearly dry, and free from a great proportion of grease and dirt. In theory this system has never been beaten, and it worked with success for many years, but the mechanical difficulties of working a roller under dirty water and working

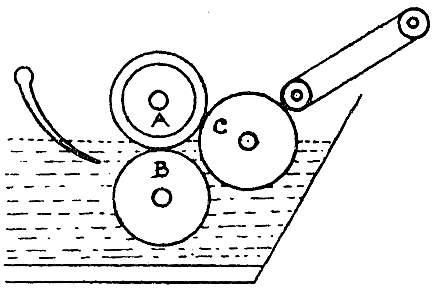


FIG. 4.

three rollers in one group, under heavy pressure, made the cost of upkeep very heavy. In addition, a portion of the wool-lapping was always under water when working, and unless it was very perfectly covered the water was not pressed out from the inner layers, and they consequently rotted very quickly.

Modern machines have another great advantage. In the hand machine and in the three-roller head, the dirt all fell back into the water in which the wool was floating, and much of the sand must have gone again and again to the rollers on many successive locks of wool, before it finally fell to the bottom of the tank.

The squeeze-head of the M'Naught machine (Fig. 5)

is designed to obviate this defect and at the same time to squeeze the wool in a condition almost equal to total immersion. The wool does not actually float into the nip of the rollers A, but it is washed forward by such a flow of water that the fibres never lie in a sodden mass, as on an apron, and they are partially separated from each other by the water they contain, so that it is easy for the sand to escape. Once away from the fibre, the sand and dirt can never come again to the rollers, for, instead of falling back into the water which contains the wool, the stream of sud from the trough B, where the wool is washed, washes the sand through the perforated plates into the trough C, from which it is pumped to the settling tank D. Here there is no agitation, and the sand quickly settles to the bottom, which is so shaped that everything falls towards the outlets, and when the cocks are opened all sediment is readily flushed clear away.

If any sud in which wool has been washed be allowed to stand, a film of insoluble matter will soon form on the surface; and if there be any salts of lime or magnesia present in the water, the scum will probably assume the character of a sticky and insoluble froth. This is the product already alluded to as lime soap.

The tank used for settling may therefore have another use of equally great if less obvious importance, for whilst its stillness allows the heavy matters to sink, it allows all insoluble oily and soapy matter to rise and float on the surface. If wool is washed in a trough A (Fig. 6), above, and quite separate from the settling tank B, these lime soaps and other floating impurities will never come into contact with the wool at all, if the sud which is to go to the washing trough be pumped from a point C in the settling tank, well above the bottom and well below the surface. In a machine of this type made by John Petrie, Jun., Ltd., the only

lime soap which could adhere to any fibres would be the very small quantity existing in a state of subdivision so minute that it could be held in suspension in the water.

In most types of machines the forks are used to move the wool through the sud, but in the type in question the forks or other mechanical contrivance may be rather said to prevent the wool being washed forward too fast by the flow of water which is pumped up and rained or allowed to flow into the trough at D, the end farthest from the rollers E.

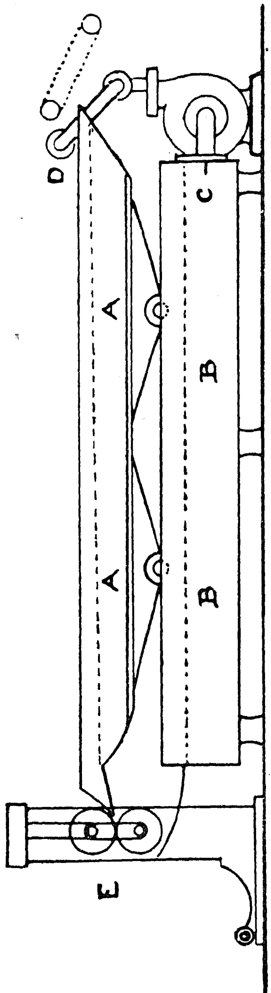


FIG. 6.—WASHING TROUGH, SETTLING TANK, AND SQUEEZE ROLLERS BY JOHN PETRIE, JUN., LTD. Forks and Fork-Motion not shown.

Fork Motions.—There are three entirely different types of fork now in general use, the oldest form being that in which each rake is driven in elliptical orbit by a separate crank. A machine of this kind is made by Messrs Hoyle & Preston. The forks work in a single deep bowl, and as they agitate the sud more than any other type, they are very suitable for slipes and other wools which are difficult to wash.

The type made by Messrs J. & W. M'Naught (Fig. 5) is simpler in its action, all the forks being fixed to

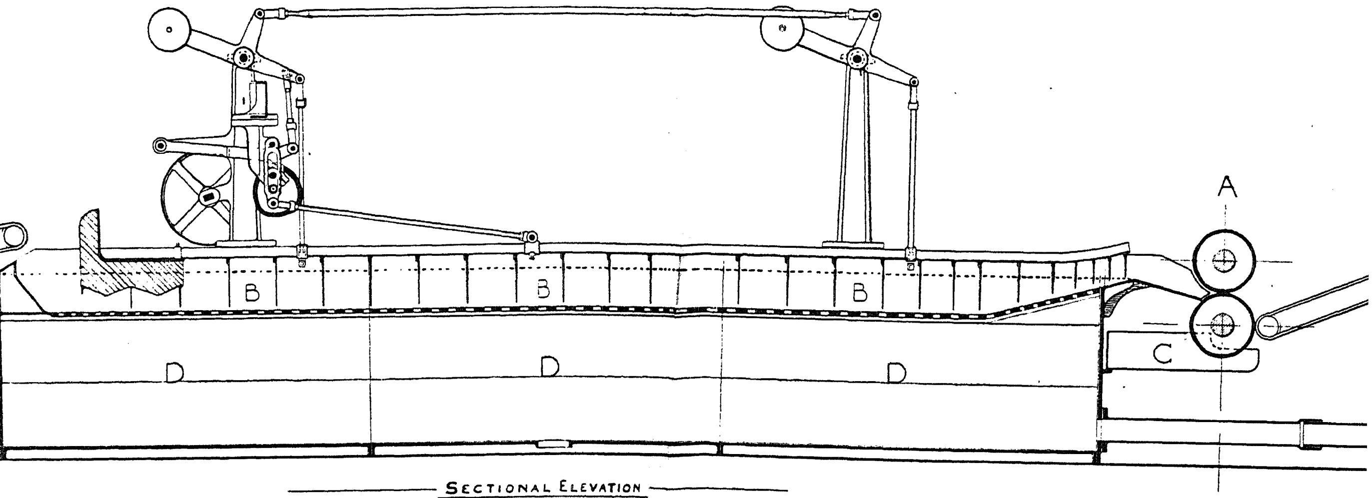
a long frame, so that they move forward together through the sud on the forward stroke, when they rise and travel back above the surface. Sometimes a shaking motion is introduced before the forks rise, to increase the washing power of each bowl.

The third type is most useful for the treatment of clean wools, the forks being attached to an endless chain which runs round rollers at each end of the bowl. The motion is steady and continuous. The forks make very little disturbance in the sud, for they are really used to retard the wool whilst the sud flows through it.

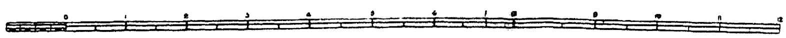
All these types are in common use, and all have their advantages, but for ordinary medium qualities the second type is most often seen, and it might fairly be said to be the most popular.

The reader may be surprised to find in this chapter no detailed description of the most modern machinery that has been put upon the market. The book is not written to advise the wares of particular firms, still less is it meant to tell a reader which machine will best suit his purpose. The most important principles which underline wool washing are stated in the simplest possible terms. They are illustrated by diagrams which have been supplied by the most important firms in the industry. The various vital principles are embodied, in greater or less degree, in every modern wool-washing machine, although it may be admitted that mechanical limitations have hitherto prevented the adoption of a design that would be theoretically perfect.

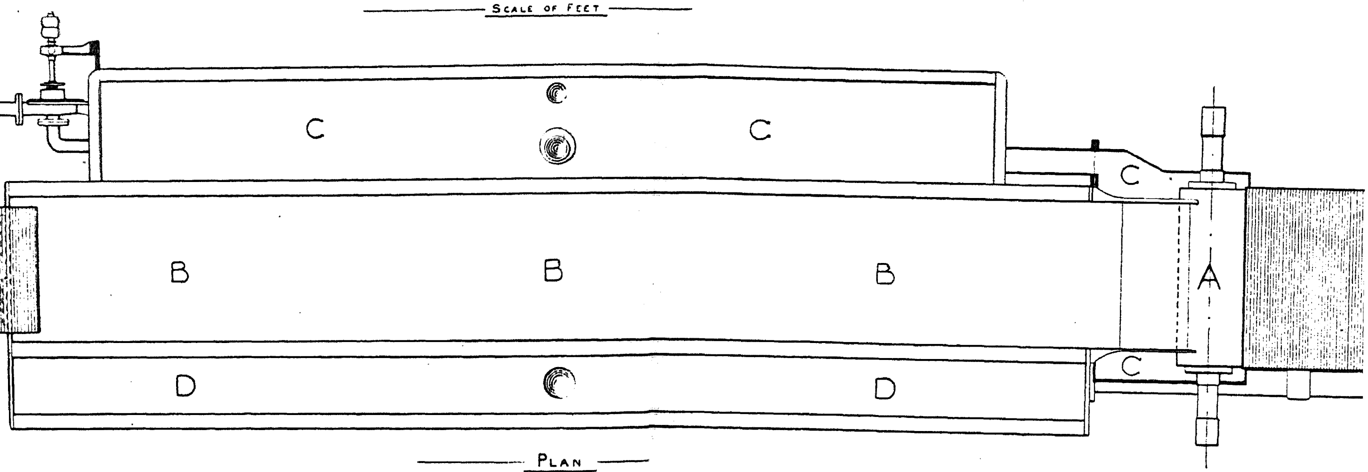
Since the first edition of this book was published relatively little alteration has taken place in regard to the theory of wool washing, but the enormous advance in the cost of labour has raised the question of output to a place of importance out of all proportion to that it used to hold. From the very earliest days efficiency in the cleansing was always recognised as being indis-



SECTIONAL ELEVATION



SCALE OF FEET



PLAN

PATENT WOOL WASHING MACHINE BY JOHN & L McNAUGHT ROCHDALE.

pensable to makers of first-class goods. It is just as indispensable to-day. The sand, the suint, the grease, and all other impurities must be thoroughly, but not too thoroughly, removed; at the same time there must now be the utmost efficiency as to output.

It should be the aim of every mill manager to maintain the maximum output from every machine through every working hour, and to this rule machine makers are turning their attention. It is notorious that the removal of exhausted suds and the making of new ones in all existing washing plants occupies time which may vary from 10 to 30 per cent. of the working week. It is obvious that any means that can be taken to remove this cause of loss must be of no inconsiderable advantage and should receive the most careful attention. Design and careful margin can also save no small amount of money in the steam used to heat the suds, and a great stride has recently been made towards the solution of this problem by John Petrie, Jun., Ltd., of Rochdale.

In this machine the sludge formed by the sand and other insoluble matter is kept continually moving towards the outlet by heavy screws located in the bottom of the settling tank. By this means stoppages are reduced to a minimum, or in favourable circumstances eliminated altogether. A set of these bowls has been worked without cessation for days, new suds being continually introduced at the finishing bowl and finding their way towards the larger bowls at the beginning of the process. Steam for heating, soap, and alkali are thereby saved, and the cost of overhead charges is reduced in proportion to the increased number of hours during which the machine is in active operation each week.

The total saving in wages and overhead charges must be set against the extra cost, depreciation, and upkeep of the machinery. It is for each user to decide

on the actual value of the invention for his own purpose, but there can be no doubt that the height of wages must tend more and more to the increased use of all such automatic aids to industry. Increase of output must be considered from every angle where new machinery is being installed, and the possibility of altering old machinery to automatic methods seems likely to become a pressing need in all industry.

Oiling.—In the " good old days " the amount of oil necessary for carding was put on to the wool through the simple medium of a garden watering can with a coarsely perforated rose or T spout.

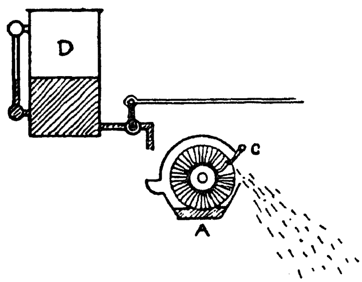


FIG. 7.

In some cases the oil was measured, but quite as often as not the amount for any given quantity of wool was guessed. Probably the guessing was almost as efficient as the measuring, for as soon as it was oiled, the wool was thrust into the " boxes " or trucks, in which it was taken to the cards. It was quite impossible for the oil to permeate the whole load in the short time before the wool was fed on to the card, and it may safely be surmised that half the fibres were carded without a particle of oil to lubricate them, whilst many others had so much that they would stick together and to the wires. Wool is oiled in a very different manner now. One of the simplest methods is the well-known rotary brush motion (Fig. 7) in which the circular brush B picks up oil from the trough A, and as the bristles bend against the knife C and spring straight on passing it, the oil is thrown down as a fine spray.

The oil tank D has a sight glass and regulating tap, so that the amount of oil running into the trough in a given time can be accurately measured and regulated, and the whole instrument is fixed above the pile of wool which falls from the rollers and the fan which clears them. The oil spray ceases directly the rollers stop, because the brush B is driven from the roller shaft or wheels in gear with it, and a connection is made to the tap of the tank, which automatically stops the flow of oil when the machine is thrown off.

If the sight glass be plainly graduated, it is very easy to regulate accurately the quantity of oil applied to any lot or pile of wool; and as the oil is always falling in an almost invisible spray, every lock of wool receives its allowance as it leaves the rollers, and no wool can go to the card with too much or too little lubricant.

There are many more complicated apparatus on the market than this. In one case, after the application of finely divided oil, the wool was pressed between heavy and hot iron rollers, which spread every drop of oil over a large surface of fibre. Probably they did their work very well, but there is always a chance of the wool being cut between two metal surfaces; and as there is always a short interval between the processes of washing and carding, there is time for the fine oil spray to spread and be absorbed without artificial aid.

Different men will always incline to different methods, and it is improbable that finality has been reached in this process. For example, powerful pneumatic spray diffusers might well be used for the purpose. Only three things are essential, and if these are attained the method is of little moment.

1. The amount of oil applied must be easily measured, recorded, and regulated whilst the machine is running.

2. The oil must be finely divided when applied to the wool.

3. The oil must be applied to every lock of wool which passes through the rollers.

With any system which fulfils these conditions a careful washer will obtain the best condition for carding at the least possible outlay, and as good oil is a large item in a comber's expenditure, such economy may be of substantial amount.

Transport.—In the planning of a combing plant every machine should be so laid down that the distance from its delivery-head to the creel of the next machine is as short as possible. Loose wool, cans or balls, may then go from one process to the next with as little handling as possible. This means that the wool will not be matted or the balls torn in transit, and at the same time, time and wages will be saved. The methods employed in moving cotton are automatic. They are, therefore, much more perfect and much cheaper than the methods employed for wool. During the three opening processes the cotton is not touched by hand, and often travels long distances by means of air pressure. For years the makers of this pneumatic transport for cotton refused to take any responsibility for the erection of similar arrangements for the conveyance of wool; but a similar system has lately been tried in the worsted trade both for wool and noils. It has the great advantage of delivering the wool to the card in a much less matted condition than is the case when the wool, still moist and soft from the washing rollers, is crammed into wooden boxes or trucks, for conveyance and storage. It is said that the moisture and oil are a great drawback to pneumatic transport, as they are bound to leave some deposit in the tubes through which the wool travels; but the difficulties of directing and controlling the supply of wool direct from the washing machine to the card have been overcome. Opponents of the system

claim that the fans and tubes require such frequent attention that there is no saving of wages. This may or may not be true of existing plant. Experience will lead to improvements, and the absence of rolling, matting, and squeezing in the boxes is a point which will well repay attention.

In some cases the wool is washed on the floor above the carding and is dropped through shoots to the bins. Perhaps some modification of this system would be the best solution of all.

Drying.—There must of course always be difference in temperature and strength of the suds used respectively for washing crossbred and Botany wools, but the general principles of treatment vary so little, that up to this point no special division has been made. In drying, however, it is different. Few if any firms do anything to dry Botany wool after it leaves the washing rollers, but it is well recognised that squeezing alone cannot take sufficient water from long wools to make them fit for carding or preparing, and hot air has long been used to dry the wool as quickly as possible.

In the old-fashioned drying-tables the wool was simply spread over steam-pipes on a support of wire netting, through which the warm air was driven slowly by a small fan, and the wool was removed when it seemed sufficiently dry. In large establishments this system kept many men employed, and the tables occupied a great deal of room; it took so much time that there was always a good deal of wool under treatment; and as the hot air naturally found its way through the most thinly covered places, the drying was far from regular, some wool being dried too much and some too little.

Many machines have been devised to take the place of this old-fashioned method, to save the expense of hand work and do the work more uniformly. To dry

the wool quite evenly throughout, it is necessary to change its position frequently, and this must be done in such a way that no rolling or matting takes place.

A good machine is designed—

1. To get all the wool uniformly dry.
2. To regulate the amount of moisture in the wool exactly.
3. To avoid all rolling or matting.
4. To save all possible wages.
5. To economise space as much as possible.
6. To cost as little as possible in steam and power.

There are several machines which attain these ends. The one here described is made by John Petrie, Jun., Ltd., of Rochdale. Machines, of course, vary greatly in size—one which will turn out 80 to 90 packs a week being 20 ft. long by 11 ft. high and 4 ft. 6 ins. wide, with 5 shelves or tables one above the other (see Fig. 8). Wool is fed straight from the washing rollers on to the feed-sheet automatically, and as soon as it is through the feed-rollers it is lifted by the strong current of hot air from the fan and heating chamber on to the fifth or highest table. This table consists of two series of bars, one stationary and the others having a reciprocating motion, as well as a motion to make them rise and fall; when they move forward they are above the level of the fixed bars, and as they travel back they are below. By the forward movement the wool is lifted, carried forward a few inches, and again deposited on the fixed bars. The return of the bars being below the mean level has no effect on the wool, so that it gradually travels the whole length of the table, until it reaches the end and falls down on to the shelf below. This method of moving the wool is designed to obviate all rolling whilst the wool travels over the tables. Wool takes about twenty-five minutes to go through the machine, and it emerges light and uniformly dried at the delivery sheet.

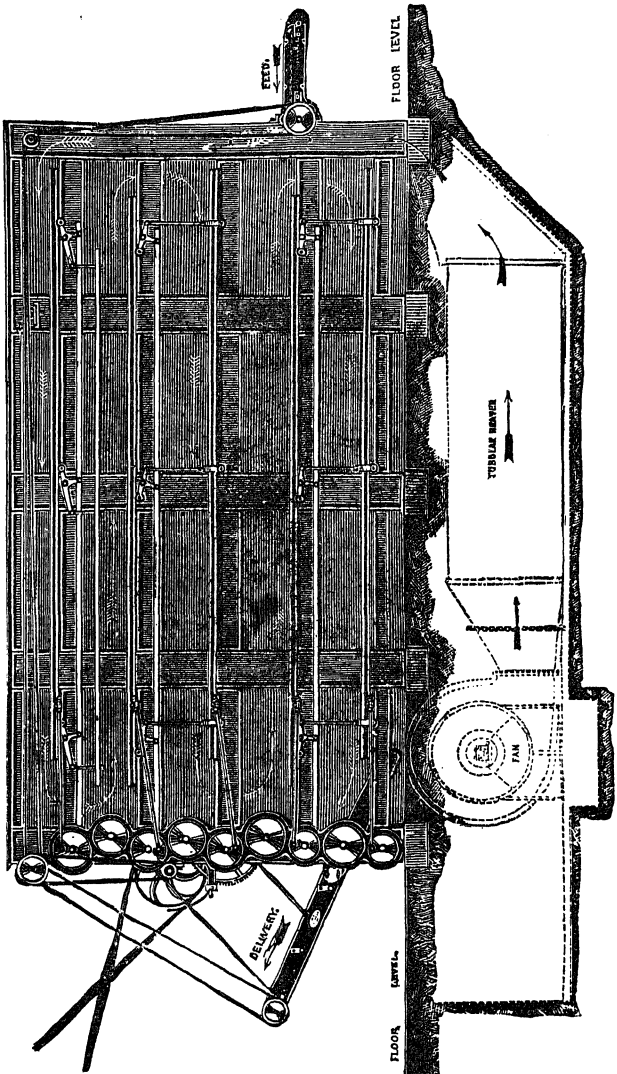


Fig. 8.—Drying Machine, by John Petrie, Jun., Ltd

The current of hot air follows the same course as the wool: it has therefore the greatest drying power where

the wool is dampest, it tends to help the wool forward on its journey, and as the wool falls from table to table the air blows through it, keeping it light and free.

The temperature is capable of such alteration that the wool can be delivered in any desired condition. It may be only partially dried or have every bit of moisture taken out of it.

Several machines by other makers are built on similar lines, differing chiefly in the manner in which the wool is moved along the tables; some have simple open lattice aprons which carry the wool forward as it falls on to them one after another from the sheet above.

All modern machines are much alike in appearance, but there are two types that are quite opposite in theory.

In the first, already described, the wool enters at the same point as the hot air, and travels in the same direction along its whole course. In the other, the hot air goes in at the bottom and out at the top, the wool descending against this current.

The temperature of the air ought never to be very high: 60-70° C. or 140-160° F. is quite sufficient for the drying; but the same, or similar, machines are also used for baking or carbonising wool after it has been acidified, and for this purpose a great deal higher temperature is necessary. Many firms use air at a temperature of 212° or thereabouts in order to drive off every particle of moisture from the acidifient cellulose, and if this temperature is only reached after the wool is perfectly dry it does not seem to have any very harmful effect on the fibres.

It is true that burrs and cotton can be carbonised at a lower temperature, but the length of time required is proportionately increased, and as loss of working time or slowness of output is a very important thing nowadays, the higher temperature is often used on grounds of economy alone.

CHAPTER III

WATER—ITS TESTING AND SOFTENING

It may safely be laid down as an axiom that suitable water is an absolute essential if the best results are to be obtained in wool washing; and as it seldom happens that such water is obtainable from natural sources, it is now very usual to extract impurities and reduce the hardness of unsuitable water before using it for washing wool. Waters containing excess of lime or magnesia salts in particular may do so much injury or cause so much expense in washing that they must be softened before they are used.

Water obtained from almost every source will vary in the quantity of its chemical constituents from time to time, and it is therefore difficult for anyone to lay down a set of rules which can be followed month after month by the user, so as to give the best results in softening and washing, unless the user have some acquaintance with the nature and action of the various salts contained therein. A thorough if simple grounding in chemistry will amply repay anyone who has the management or oversight of a scouring plant, for without such knowledge, no length of experience will enable a man to decide for himself how to remedy, alter, or prevent any reaction which may take place in the bowls. Such actions are always present: the salts of the water affect the alkali, the soap and the wool fat, or the alkali and soap themselves act in turn on the wool grease and the fibre, in ways which may be very beneficial or very harmful, and which are always so

complicated that sufficient knowledge to understand them clearly can never be obtained by reading only.

For the purposes of wool washing the impurities in water may be classed under three heads.

1. Organic or other matter in suspension.
2. Salts producing hardness.
3. Other salts producing little or no effect on soaps or fats.

Any matter which is held in suspension makes water appear dirty and unsuitable for washing, and nearly always occurs in streams which are fed or have their origin in surface drainage. This suspended matter can always be removed by filtration, and it may therefore happen that, after simple treatment, such turbid water is more suitable for washing than perfectly clear water from springs, which may, on the other hand, contain sufficient matter in perfect solution to do great harm to the wool, or destroy large quantities of soap. For instance, water from a limestone spring often contains more than 30 grains of lime salts to the gallon, and as each grain of carbonate will combine with 13·1 grs. of the fatty acids in soap, a bowl containing 1,000 gallons of this water would destroy about 25 lbs. of the best soft soap before any washing began.

As a matter of fact, no satisfactory washing could be conducted with such water, for the decomposed soap would float on the top of the water in the form of a sticky scum which would adhere to every fibre put into it; and as the lime salts are themselves alkaline and have more affinity for the fat acids in the soap and the wool grease than have the carbonates and hydrates of soda and potash soaps, it follows that no addition of alkali to the water will prevent this action.

There are two kinds of hardness—

1. Temporary hardness, which is due to the carbonates of lime and magnesia, which are only soluble in water containing carbonic acid, and are therefore precipitated when the CO_2 is driven off by boiling or by the addition of lime.

2. Permanent hardness, caused by the presence of sulphates and chlorides of lime and magnesia, which are soluble in pure water and are not quite so easy to estimate accurately.

Total hardness includes both permanent and temporary, and as all the salts have so great an affinity for the fatty acids in soap and oils that they will decompose soda and potash soaps to form lime soap, and as each grain of lime will unite with twice as much palmitic, oleic, or stearic acid as will one grain of potash, it is the total hardness that is of primary importance to the washer.*

For the purposes of the wool scourer, the soap test which was devised by Dr. Clarke of Aberdeen, and published by him about 1841, is by far the easiest method of computing total hardness. His system of degrees is based on the estimation of the number of grains of calcium and magnesium salts in every gallon of 70,000 grains—that is to say:

Water of	1°	hardness	contains	1 grain in 70,000.
,,	2°	,,	,,	2 grains in 70,000, *et seq.*

And as the washer still estimates the contents of his bowls in gallons, the original tables are still the simplest for use in factories; but in view of the more general adoption of the decimal system, and its greater sim-

* Oleic potash soap formula—

$$\begin{array}{cc} C_{17}H_{33}CO_2 & K \\ \underbrace{204+33+12-32}_{281} & 39 \end{array} +39=320$$

Oleic lime soap formula—

$$\begin{array}{cc} \left.\begin{array}{c} C_{17}H_{33}CO_2 \\ C_{17}H_{33}CO_2 \end{array}\right\} & Ca \\ \underbrace{408+66+24+64}_{562} & 40 \end{array} +40=602$$

plicity in calculations, it is now more general to state the total hardness simply in parts per 100,000.*

By careful research, Dr. Clarke ascertained exactly how much soap dissolved in alcohol was necessary to combine with 1 grain of lime salts, calculated as carbonate, and he then prepared a solution of such a strength that each cubic centimetre would contain that quantity of soap. This solution was composed of 10 grams of Castile soap in rather less than 1 litre of alcohol. This solution is tested against water of known hardness, and brought up to standard by the addition of such a quantity of alcohol as will make it the requisite strength. To make a test 70 c.c. of the water is measured into a stoppered bottle of 250 c.c. capacity, and soap solution run in carefully from a burette. After the addition of each c.c. of soap solution the bottle is stoppered and violently shaken. The lime and magnesia salts will be neutralised, when a lather is developed which will remain intact for five minutes or more.

When this point is reached the number of c.c. of soap solution taken from the burette, minus 1, will be the grains of hardness in every gallon of water. The reason for the deduction is simple. Distilled water, which contains no hardness of any kind, will clearly require some soap to make it lather: in practice it is found to need 1 c.c. of the standard solution in every 70 c.c. of water. Water, say, from granite strata of 3° hardness will require 3 c.c. soap solution to neutralise its salts, and 1 c.c. more to make a lather; the burette would therefore read 4 c.c. But 4 minus 1 equals 3. Therefore 3 is the true number of degrees of hardness. For hard water the reading might be 11 c.c. and the true number of degrees 11 minus 1—that is, 10.

* German degrees are parts of CaO per 100,000 and in England they are sometimes stated as parts of $CaCO_3$ per 100,000.

The whole process is eminently one which will appeal to practical men, for it is a reproduction in miniature of what will happen in the bowls. When enough soap solution has been added to neutralise the salts and create a lather, a calculation, based on the appended figures, will give the amount of soap necessary for use in a bowl of similar water.

$$\begin{aligned} 1 \text{ gallon} &= 10 \text{ lbs.} = 70{,}000 \text{ grains.} \\ 70 \text{ c.c.} &= 70{,}000 \text{ milligrams.} \end{aligned}$$

Therefore the relation of 1 milligram to 70 c.c. of water is exactly the same as that of 1 grain to a gallon;

but 1 kilogram = 2·205 lbs. of 7,000 grs. each,

$$\therefore \quad 70 \text{ c.c.} = \frac{70}{1{,}000} \times \frac{2{\cdot}205 \times 7{,}000}{1} = 1{,}084 \text{ grs.}$$

$$\left.\begin{array}{lll} \text{But if} & 70 \text{ c.c.} & = 1{,}084 \text{ grains} \\ \text{and} & 1 \text{ gall.} & = 70{,}000 \quad ,, \end{array}\right\} 70 \text{ c.c.} = \tfrac{1}{65} \text{ gallon,}$$

and the c.c. of soap solution used to neutralise 70 c.c. of water $\times$ 65 = grains hardness in a gallon.

Therefore to find the amount of soap necessary to soften 400 gallons of water 30° hardness we take

$$\frac{30^\circ \text{ hardness} \times 65 \times 14 \times 400}{70{,}000 \text{ grains per gallon.}} = 39 \text{ lbs.}$$

The soap test cannot be described as a purely chemical reaction, but rather as a physical effect consequent on a chemical change, and for this reason it cannot be relied upon to indicate the exact number of grains to the gallon of the salts which make the water hard, because magnesium does not affect the soap in the same way as calcium, and when both exist in the same water it is not easy to ascertain their proportions. (See Wanklin's "Analysis of Water.") It is in very hard waters that the soap test is the least accurate. Soap in alcohol will never cause a permanent lather, however much it be shaken. To produce a lather on water of 20° hardness 20 c.c. of soap solution would be added—

that is 20 c.c. of alcohol with the necessary soap dissolved in it. When the test was complete the bottle would contain 70 c.c. water, 20 c.c. spirit, besides the necessary soap, and the effect with the spirit present will not be exactly the same as if the soap were dissolved in 70 c.c. water. It is also probable that the lime soap formed in the solution will tend to rise and blend with the lather, reducing it in extreme cases, even after all the salts are reduced and some surplus soap exists in the solution.

If water is to be softened effectively and cheaply, it is essential that the exact amounts of permanent and temporary hardness should both be known, and for this purpose no method is at once more simple and accurate than that devised by Hehner. The only apparatus necessary are two burettes for measuring any liquid drop by drop, an evaporating dish, a Bunsen burner, a filter, some flasks or beakers for titrating, and some indicating medium to show when a solution is acid and when alkaline. Methyl orange is most suitable, being yellow with alkali, pink with acid.

An acid and an alkali are also wanted, and they must be in solution exactly equal in strength, so that if 10 c.c. of the alkali be put in a beaker with a drop of methyl orange, 10 c.c. of acid would alter the colour slightly, and 1 drop more than 10 c.c. would change the colour to pink. The amount of acid or alkali in such solutions is always in direct relation to their respective molecular weights.

Carbonate of soda (Na_2CO_2) and hydrochloric acid (HCl) are the most convenient reagents to use. The molecular weight of dry sodium carbonate is 53. To make a normal solution of carbonate of soda, 53 grams are dissolved in 1 litre (1,000 c.c.) of distilled water. This solution will always be referred to as N/1 Na_2CO_3,

and when it is in deci-normal solution—that is, one-tenth the strength, it will be written with N/10 instead of N/1 before it. 10 c.c. will neutralise exactly 10 c.c. of a solution of hydrochloric acid, 36 grams in a litre (written N/1 HCl), because the molecular weight of HCl is 36, and 36 atoms would therefore be required to unite with 53 atoms of Na_2CO_3.

To ascertain the temporary hardness, 100 c.c. water are measured into flask or beaker with one or two drops of methyl orange indicator. Deci-normal HCl is then run in from the burette until the colour changes to pink, and each c.c. of acid used must be multiplied by 5 to give grams of temporary hardness taken as carbonate of calcium, in every 100,000 grams water, or if multiplied by 3·5 it will give grains temporary hardness per gallon.

The permanent hardness may be ascertained approximately by deducting the temporary hardness (Hehner) from the total hardness given by the soap test; but for accurate estimation Hehner's method must be followed throughout.

To convert the soluble sulphates, chlorides, etc., of calcium and magnesium into insoluble carbonates, he added 20 c.c. of N/10 Na_2CO_3 to 100 c.c. of the water to be tested, and evaporated the whole to dryness in a basin—the object being to see how much of the Na_2CO_3 will be neutralised in the process. This he ascertained by treating the contents of the basin with cold distilled water and washing the remainder on a filter paper. Any portion of the Na_2CO_3 which was not required to combine with the chlorides and sulphates will at once dissolve and go through the filter paper, whilst all the insoluble matter will remain. If methyl orange be now added to the filtrate, and it be titrated till exactly neutral with N/10 HCl, the difference between the c.c. of HCl and the original 20 c.c. of Na_2CO_3 will be the c.c. required to combine with the

chlorides and sulphates present in the 100 c.c. of water; and this figure multiplied by 5 will give the parts of permanent hardness per 100,000 estimated as $CaCO_3$, or multiplied by 3·5, the grains of permanent hardness per gallon.

Softening.—When water is to be softened the sulphates and chlorides forming the permanent hardness must be treated quite apart from the carbonates or temporary hardness.

Carbonates of soda or potash will destroy the permanent hardness by acting on the sulphates and chlorides of lime and magnesia, and if the amounts of each have been accurately ascertained, the exact quantity of carbonate can be easily calculated. But the addition of carbonate of soda to carbonate of lime will cause no material change in either salt, and the temporary hardness is therefore quite unaffected by such addition. To remove the temporary hardness of any water it is necessary that the carbonic acid must be driven off or combined before the bicarbonates can be precipitated, because it is only the presence of the CO_2 which makes the bicarbonates soluble.

There are two ways of effecting this—

(1) by boiling;

(2) by the addition of lime or caustic soda.

To boil a large quantity of water daily and allow ebullition to continue for half an hour would cost a great deal, in fuel alone; and the precipitate would settle on the sides and bottom of the vessel as a hard scale, very difficult to remove and very liable to cause injury to the vessel if allowed to remain, because it would prevent rapid transmission of heat to the water, and there would be undue expansion and contraction in consequence.

The use of lime to absorb or combine with the CO_2

is a far better method of attaining the same end, because an insoluble carbonate of lime is formed by the combination, and is precipitated with the lime and magnesia which formed the hardness, and which become insoluble as soon as the water is free from CO_2.

By these reactions all the added lime as well as the CO_2 and the carbonates in the water fall to the bottom, and nothing is permanently added to the water, so that it is suitable for washing, or even for drinking, *when due time has been allowed for the precipitate to settle or be filtered off.*

This process is not always popular, but the fault does not lie with the process but with those who misuse it. If washing be attempted before the precipitate has thoroughly settled or has been filtered off, the added lime and the original carbonates are both present to attack the soap, with worse results than if no softening had been attempted. After lime has been added the water must be allowed to stand 12 hours before precipitation is complete, and if sufficient space cannot be spared for settling tanks for this purpose, the water *must* be filtered before being used.

If too much lime be added either through carelessness or miscalculation, or through variation in the temporary hardness, the remedy becomes worse than the original disease, for the surplus lime is absorbed by the water, and is then free to combine with any oils or soaps with which it comes into contact. An elementary knowledge of chemistry will prevent such a mistake. If a few drops of phenol-phthalein be added to the water after treatment, it will be turned purple by the presence of any free lime, and titration with N/10 HCl until the colour disappears will give the exact surplus in a given quantity.

Messrs Archbutt & Deely patented a process to quicken the settling of the precipitate by stirring up

the sediment remaining from previous charges by steam jets. Curiously enough, this greatly accelerated precipitation and enabled them to clear the water much more quickly. (See *Jour. Chem. Indust.*, p. 511, 1891.)

For removing permanent hardness either carbonate of soda or carbonate of potash is equally effective; but the former, being cheaper, is more generally used. Under certain circumstances when the amounts of permanent and temporary hardness are about equal, caustic soda might be used instead of the lime and carbonate of soda. In this case the caustic soda first affects the carbonic acid, precipitating calcium carbonate and leaving in solution carbonate of soda, which is free to combine with the calcium sulphate (permanent hardness).

$$\left.\begin{matrix} CaCO_3 \\ H_2CO_3 \end{matrix}\right\} + 2NaOH = CaCO_3 + Na_2CO_3 + 2OH.$$

Difficulties arise when the hardness is due to a combination of magnesium and calcium salts, because the two do not combine in the same way with the softening agents, and this makes it important that the relative quantities of calcium and magnesium salts should be ascertained before softening is attempted. The accurate estimation of these different salts is far too complicated a process to be of interest here, and readers are referred to chemical textbooks, but the total magnesia salts may be ascertained by the following simple method:—

Take 100 c.c. of the water to be tested in a flask and add 1 gram c.c. of oxalate of ammonia solution (1 gram in 100 c.c.); to precipitate the carbonate and sulphate of lime, shake and filter the solution, and if there has been excessive precipitation, add a further known quantity of ammonium oxalate in solution, and refilter. Take 70 c.c. of the filtrate and treat with standard soap solution: any remaining hardness is due to magnesium salts.

The number of c.c. of soap solution $-1 \times \cdot 56$ equals the grains per gallon magnesium carbonate.

For example, 17 c.c. soap solution $-1 = 16 \times \cdot 56$ equals 8·96 grains of magnesium carbonate per gallon of Leeds water.

Alkalies.—To ascertain the relative values of samples or bulk lots of alkalies, the burette with normal HCl will be of great value to the user. By dissolving and titrating a similar weight from any 2 or more samples of carbonate or hydrate of soda or potash, the exact relative strength of each can be quickly obtained.

For instance, if 2 samples of soda ash and 1 of crystal carbonate be submitted to a buyer, 1 gram of No. 1 is carefully weighed and dissolved in 100 c.c. distilled water in a flask or beaker, 1 or 2 drops of methyl orange are added, and HCl is run in drop by drop from the burette until the orange colour changes to a distinct pink; the number of c.c. HCl used are then noted. Samples 2 and 3 are then treated in the same way, and the amount of acid required to neutralise each is in exact proportion to the relative values of the samples.

Let us say—

1 gram of No. 1 requires 14·6 c.c. N/1 HCl to neutralise it.

1 gram of No. 2 requires 14 c.c. N/1 HCl to neutralise it.

1 gram of No. 3 requires 12 c.c. N/1 HCl to neutralise it.

These figures are in direct proportion to their values, and the percentages of sodium salts expressed as carbonate can be ascertained by multiplying by the atomic weight 53 and $\frac{100}{1000}$, sample 1 containing 77·38 per cent.; sample 2, 74·2 per cent.; sample 3, 63·6 per cent.

The same method can, of course, be adopted to see that bulk lots continue to be delivered equal to sample,

and it will give equally good results with caustic soda and potash.

In each case 1 gram is dissolved in 100 c.c. water prior to titration, or for ease and accuracy in weighing 100 c.c. may be taken from a solution of 10 grams in a litre of water, and several tests may be made from each. The HCl is normal in all cases, and the indicator methyl orange.

1 gram soda ash + methyl orange = 14·6 c.c. N/10 HCl × ·053 × 100 = 77·38 per cent. alkali present as carbonate of soda.

1 gram caustic soda + methyl orange = 20·4 c.c. N/10 HCl × ·04 × 100 = 81·6 per cent. alkali present as sodium hydrate.

1 gram pearl ash + methyl orange = 8·2 c.c. N/10 HCl × ·069 × 100 = 56·58 per cent. alkali present as carbonate of potash.

1 gram caustic postah + methyl orange = 13·5 c.c. N/10 HCl × ·056 × 100 = 75·60 per cent. alkali present as potassium hydrate.

The relative strength of the alkalies is shown by the amount of acid required to neutralise them, and it is with these figures that the relative prices should be compared, because the percentages are influenced by the molecular weights of their component elements, and do not show their relative ability to combine with fat acids.

In their commercial forms these alkalies are all more or less impure. Soda ash often contains a small percentage of hydrate, and a proportion of carbonate is nearly always found in caustic soda. The same thing is true of pearl ash and caustic potash, and to find the relative proportions a double reaction is necessary.

In a soda ash the total alkalinity present as sodium carbonate must be ascertained as before,

1 gram being equal to 14·6 c.c. N/10 HCl or 77·37%.

To 100 c.c. from the same solution, 100 c.c. of (5 per cent.) barium chloride solution are added. This combines with all the carbonate present and deposits it as a heavy white precipitate, but it leaves the caustic still in solution. After filtering and adding methyl orange 200 c.c. of the filtrate (containing 100 c.c. of the original solution) must be titrated till neutral with N/1 HCl: if ·6 c.c. are required it means that carbonate equivalent to 14 c.c. N/1 HCl has been precipitated by the barium chloride. In other words, the sample contains—

Carbonate equal to 14 c.c. N/1 HCl, or $14 \times \cdot 053 \times 100$ or	74·2 %
Caustic equal to ·6 c.c. N/1 HCl, or $\cdot 6 \times \cdot 04 \times 100$ or	2·4 %
Total alkali . .	76·6 %

For complete analysis of water and alkalies readers must refer to textbooks of applied chemistry, such as those by Wanklyn on "Water Analysis," or Allan's "Commercial Organic Analysis," and for soap analysis to Benedict and Lewkowitsch's "Oils, Fats, and Waxes."

Soap Analysis is so complex that few practical men will attempt it for themselves; but every user is called upon to judge of the strength and value of the soap which he has offered, and the intelligent use of the apparatus already mentioned will enable anyone to form some idea of the free alkali, combined alkali, and the amount of fats and oils used in the manufacture.

For a commercial test 10 grams of soap should be weighed and dissolved in 150 c.c. of water, and kept at about 120° F. throughout the test. If 2 drops of phenol-phthalein are added, the presence of any free caustic soda will turn it purple, and the quantity can

be ascertained by running in N/1 HCl till the colour disappears. Thus, for example, we find

10 grains soap + 150 c.c. water + phenol-phthalein $= 5$ c.c. HCl, or $5 \times \cdot 039 \times 100 = \cdot 195\%$ free caustic.*

Three drops of methyl orange are now added, and the solution is again titrated with N/1 HCl until all the alkali is neutralised and the colour turns permanently pink. The burette now reads 15·5, so that 15 c.c. have been used to neutralise the combined alkali, and therefore

$$15 \times \cdot 039 \times 10 = 5 \cdot 85\% \text{ combined alkali.}$$

A more accurate method of ascertaining the total alkali is to add exactly 50 c.c. N/1 HCl to the solution at once; this will turn the solution distinctly acid, the fats will be entirely freed and when heated will float on the surface of the liquid. After the fat has been removed, the solution must be titrated back to neutrality with N/1 Na_2CO_3, the difference between the c.c. Na_2CO_3 and the original 50 c.c. HCl being the c.c. HCl used to neutralise all the alkali present in the soap: thus—

10 grams soap + 150 c.c. water + 50 c.c. N/1 HCl $= 34 \cdot 5$ c.c. N/1 Na_2CO_3

$\therefore$ 10 grams soap + 150 c.c. water $= 15 \cdot 5$ c.c. HCl.

The tallow and other fats used in the making of hard soaps will generally harden into a stiff cake if the vessel be allowed to cool, and this cake can easily be removed, dried on a filter paper, and weighed.

If the fats will not set at normal temperature the addition of a known weight of stearine will cause them to solidify. From 10 grams of a standard hard soap the fat cake would weigh about 6·92 grams or 69·2%

* If the free alkali present is partially carbonate this method is inaccurate, and the solution must be made in alcohol, in which the carbonate is insoluble.

of the total, and that from soft soap, to which 3 grams of stearine had been added, say—

	8·18 grams	
Less	3 ,,	added stearine
	5·18 grams, or 51·8%	

The weighing of such small quantities with accuracy involves considerable time and quiet, and as a volumetric method would be both quicker and easier, the following is suggested as a simple method of comparing samples:—

Dissolve 10 grams soap in a beaker and pour the 150 c.c. solution into a 250 c.c. flask with a graduated neck (see Fig. 9); rinse out the beaker with hot distilled water and add it to the solution in the flask. Now add sufficient acid to decompose the soap, so that the fats will float as shown. Immerse the whole flask in a deep beaker of boiling water to keep the temperature constant at 100°, and gently add boiling distilled water until the surface of the oil reaches the mark zero. The oil will all have collected in the graduated neck (Fig. 10), and the number of c.c. can be read off at once. In the case of the hard soap there would be 8·15 c.c., and as the specific gravity at 100° is very near ·85, we find that the weight would be—

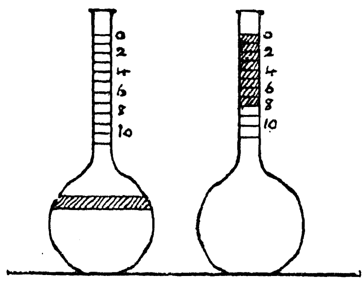


FIG. 9. FIG. 10.

$8{\cdot}15 \times {\cdot}85 = 6{\cdot}92$ grams, or	69·2%	fat acids
	5·85%	combined alk.
	·195%	free alkali
	24·755%	water, etc.
	100·00%	Total

The equivalent figures for a good olive oil soft soap might be—

58 c.c. $\times \cdot 85 = 4 \cdot 93$ grams or	49·3%	fat acids
	2·4%	combined alk.
	6·55%	free carbonate
	41·75%	water, etc.
	100·00%	

Oils for Wool.—The chemistry of oils and fats is so complicated that no passing reference to it would be of any service here, and students of the subject are referred to Benedict and Lewkowitsch's exhaustive treatise on oils, fats, and waxes. The value of good and suitable oil for the lubrication of wool is not easy to over-estimate, and it is a matter of common knowledge that there is nothing better than good olive oil for combing qualities, because it does not dry, and only oxidises slowly, in proportion as it contains little or much free oleic acid.

Many of the best brands of oil from Italy may contain as little as 5% of free oleic acid, and at times lots from Crete and southern Spain may be found below this limit. These may be safely used for any kind of work; in fact, any oil with under 8% may be used with safety. Oil containing more than 9% must be regarded with caution, because the oil will oxidise or "set" on the fibre in proportion to the amount of free oleic acid present; and even pure oils of this type are likely to become so sticky, if the tops lie long in stock, that they would need re-backwashing prior to use. Re-washing, however, would make them all right, and in this respect the poorest olive is greatly superior to the finest drying oil. When free oleic acid is present in excess the oil has a very detrimental effect on the steel pins of fallers and the wire of cards, and in a place like the backwash gill-box, where the oil is present in excess,

before it has permeated the sliver, the pins may get so rough that in a short time they are quite unfit to do fine work.

Oils which contain any cotton seed, rape seed, linseed, or other drying oils must be avoided *at all costs.* Certainly they will make the tops set quickly, but if kept for more than three weeks the fibres will be so sticky that the use of varnish would scarcely be more harmful. If drawn apart the fibres will "fly" and "whistle" in a way which will mean utter ruin to their spinning power.

Cotton-seed oil is never offered pure as a wool lubricant, but it is very cheap and so difficult to detect when blended, that users of cheap oils should always be on their guard. When it is mixed in small quantities with olive oil it is by no means easy for an experienced chemist to assess the amount of each with accuracy; and unfortunately it does not even follow now that imported oils are always pure, for cotton-seed oil is said to go to Italy "for use by the natives" in quantities too large to be ignored.

Oleine was at one time used to blend with olive oil, but it naturally increased the quantity of free acid present to such an extent that the mixture oxidised too rapidly for use on wool.

Sud Disposal.—The great difficulty of getting rid of dirty and soapy "suds" which result from wool washing is one of the problems of the trade, and the old system of decomposing the soapy liquors by sulphuric acid is still in common use. The resulting "magma" is filtered off and made up into packages in canvas, which are heated in steam ovens till the fats are melted and can be pressed out by hydraulic or screw pressure. When cool the resultant grease is dark brown in colour, known as wool grease or brown grease. It is a saleable

product, containing a large quantity of lanoline, but at times its price is so low that it hardly repays the cost of recovery.

Another method involving expensive plant is in use, and pays well where large quantities of wool are treated. The washing liquors are first condensed to about one-twelfth of their original bulk, or until the specific gravity of the fat emulsions is about ·916 and the alkaline solution 1·35. This difference makes it possible to separate the two by centrifugal machines, on the principle of huge cream separators. The fats obtained are purified in the ordinary way. The residual liquor is again concentrated almost to solidity, and this remainder is then calcined in a furnace, to destroy the organic matter contained in it. What remains consists largely of potassium salts, which can be purified by crystallisation.

CHAPTER IV

CARDING

CARDING is the first of seven mechanical processes known collectively as combing, by which raw wool, after it leaves the washing free from grease and dirt, is converted into top.

The theoretical uses of carding may be classified under three heads—

A. Those uses which are common to both woollen and worsted processes.

B. Those uses which are peculiar to worsted carding.

C. Those uses which are peculiar to woollen carding.

A. 1. The primary object of all carding is to begin the combing process, by separating the fibres from one another.

2. To arrange the fibres in a continuous riband or " sliver," all parts of which are of equal weight and thickness, so blended that all parts contain fibres of every length and quality.

3. To remove as many knots, seeds, and burrs as possible.

B. 1. In worsted, as far as possible to comb the wool and lay the fibres as straight and as nearly parallel as possible.

2. Making a sliver in which every fibre retains the greatest possible length, but one in which bulk in regard to length is of little importance.

C. 1. In woollen, the separate fibres are crossed and interlaced as much as possible to form a sliver of the greatest possible bulk, length of individual fibres being of no special value and in some cases being positively detrimental.

2. To blend fibres of different length and quality.

3. In blending colours, to mix the fibres so thoroughly that every part of the sliver is of the same shade.

The methods of obtaining these objects in the card may be classed under six distinct heads—

1. The direction in which the wires point.
2. The number of wires per inch.
3. The surface speed of the rollers.
4. The relative direction of the surface motion of every pair of rollers which work together.
5. The sizes of the rollers.
6. The distance of the rollers from one another.

As far as possible these six heads will be treated separately, but as most of them are intimately connected with one another the sequence of the following paragraphs is not entirely in accordance with the above table.

Before considering the intricate arrangements of wires involved in carding, we ought to know what are the objects attained by the process in practice, and what are the essentials of a good carded sliver. To do this we cannot do better than refer to the properties of a good top. (See Chap. XII.)

If a large lot of yarn is to be quite uniform in weight, and even throughout, six things are necessary in the combed sliver.

1. The top must be as near the original length of the wool as possible, and must not contain much short wool or noil knots.

2. The top must be quite uniform in weight throughout—that is to say, 10 yards of sliver from any one top must be equal to 10 yards from any or every other ball in the lot.
3. Long and short fibres must be blended uniformly through every part of the sliver, as explained in Chap. XII.
4. There must be no lumps or thick places due to piecings or loops.
5. All fibres must be as nearly parallel as possible.
6. There must be no burrs or vegetable fibre.

Of these heads the carder is responsible for Nos. 1, 2, 4, and 6.

Under head 1 is involved all that is essential in the carding process proper.

2. If the weight per 10 yards of carding varies from day to day, it is almost impossible for the comber to make the weight of his slivers uniform. To ensure uniformity the wool is now usually weighed on to the feed-sheet by automatic machines (see page 92), which regulate the output of the card to within a few pounds per day, and as the length delivered is always constant the weight per yard can vary very little.
4. There must be no very thick piecings in the carded or back-washed slivers. (See page 97.)
6. The carder is not entirely responsible for the removal of burrs and straws, as a small number are removed with the noil in combing, but a very large proportion should be taken out in or prior to the carding either by: (1) burr-rollers on the card; (2) crushing-rollers on the card, or before it; (3) other patent processes; (4) carbonising. (Page 93.)

It is impossible to over-estimate the necessity for care in every detail of the carding process.

Attention to the size, length, and grinding of the

wire, and care in the adjustment of the various rollers in relation to one another, for every different class of wool, will repay the time expended on them; for it is always acknowledged that no staple can go through the carding process without some of its component fibres being reduced in length, and if the work is carelessly or inefficiently done, the fibres may be so broken that the average length of the wool is seriously reduced. Length in a top is an all-important factor in worsted spinning, and it is plain that no amount of care in after processes of combing and finishing can avail to remedy the damage, for length once lost is lost for ever.

It is not the purpose of this book to go into matters which are historical only; but as the simplest and earliest form of carding by hand is a perfect illustration of the theories on which the huge modern worsted cards work, it forms the most fitting introduction to this very complex subject.

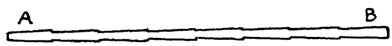


FIG. 11.

Anyone can try for himself the well-known experiment of pulling a hair from his own head and noticing in which direction it moves or which end comes out first when rubbed between the finger and thumb.

Theoretically wool should act in the same way as hair; for in diagram a single wool fibre would be represented as in Fig. 11, and it is clear that if placed between two plain surfaces having a reciprocating motion it would always tend to move towards A, the root end of the fibre, just as the head of barley will rapidly walk up the inside of a coat sleeve if it be inserted stalk end upwards at the wrist, and the arm hanging down be then shaken for a few moments.

Unfortunately it is not at all clear as yet what part this property of wool plays in the carding process, or

whether it plays any part at all; for instead of the wool being rubbed by plain surfaces it is treated by an infinite number of fine wires, all the points of which are inclined in one direction or another, and the direction in which these wires are inclined exercises the most powerful influence on the motion of the wool through the machine.

Card clothing (Fig. 12) consists of a leather or woven foundation (if woven the fibre is strengthened by thin layers of vulcanised rubber), and through this foundation wires of exactly equal length are inserted, bent to a uniform angle and inclined in one direction. The length is usually about $\frac{3}{8}$ in., but the number of points and the thickness of wire vary—in a carding-machine for Botany worsted from 100 to 500 per square inch, exclusive of the rollers covered with angular wire.

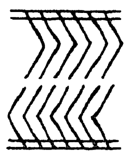


FIG 12.

The old hand cards consist simply of two flat boards, 8 ins. by 5 ins., fitted with handles and covered with card clothing arranged as in Fig. 13.

If a lock of wool were placed between the two cards, and they were moved backwards and forwards parallel to one another, it is obvious that it would quickly be held at some point along its length by one or more wires on one of the cards, say B, and that the teeth of the upper card A must then of necessity be drawn through the loose portions of the staple, separating the different hairs from one another, or combing them in a direction approximately parallel with the line of motion.

If the staple were held by its extreme point or root on any one point or set of points, the wires of the other card would card it (or one might with equal truth say comb it) from end to end so thoroughly that no after process would be necessary, *if it could be removed in the straight condition from the card;* but, unfortunately, in

practice the wool is held at some point between the two ends, and as it hangs in something like a loop on one of the cards, the teeth of the other one can only comb the two loose ends, and cannot open the middle of the staple until it has been moved from that position. When it is in this looped condition there is the greatest danger of breakage, and if two or more staples become interlaced or "felted" through careless manipulation

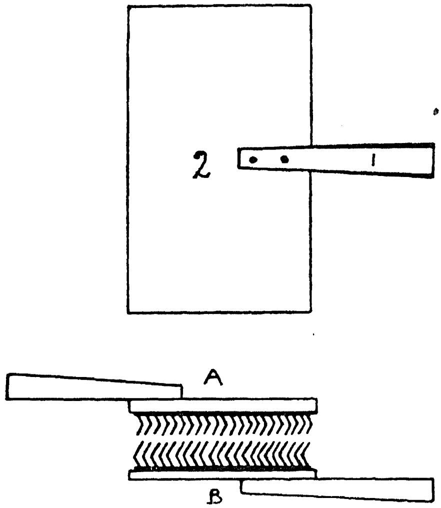


FIG. 13.

in the washing, or from any other cause, it is clear that there may be two looped ends, with the loops lying in opposite directions, so that when the cards move on one another, the fibres of one staple are bound to give way and be shortened.

In their second position, Fig. 14, the action of the cards is entirely changed. The motion continues exactly the same as before, but now that the handles are together the wires all incline in the same direction, and if A be moved towards X the teeth of B will hold

all the wool, and the teeth of A will slip easily out of it. As A again comes forward empty, the first rows of teeth will clear nearly all the wool out of B, and if the process be repeated, a few strokes will effectually empty all the teeth, and the carded wool will be lying between the handles.

The different fibres will be completely separated from one another, but they will not now be straight—the operation of clearing the cards will have rumpled them up, so that the fibres lie in all directions, often considerably curled; and although the wool in this condition is admirably adapted for spinning into woollen yarns the fibres must be thoroughly straightened again and laid as nearly parallel with one another before they are fit to be "drawn" for worsted.

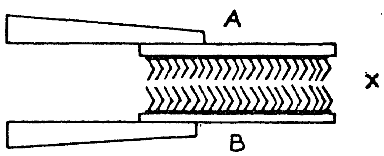


FIG. 14.

The two motions of the hand cards, or rather the one reciprocating motion, with the teeth in two altered relations to one another—illustrate the action of every roller on a modern carding-engine (except the fancy, which is really a kind of brush): but because the motion of the rollers is continuous and rotary, instead of reciprocating, there are different rollers set apart for each of the two processes effected by the hand cards in their two different positions. Every roller of a card which "works" the wool is being continually filled up by the cylinder on which it works, and as it would get very much overloaded after its first revolution a stripping roller is provided to remove the carded wool from the worker.

The angle of the clothing of the worker in relation to the wire points of the swift is exactly that of two hand cards when in their first position (Fig. 15), whilst the

motion of the stripper and the set of its wire makes the action of the stripper and worker exactly like that of the hand cards in the second position, the stripper taking away the carded wool and depositing it again on the cylinder. There is a hard-and-fast rule for all stripping rollers: they must move point first faster than the roller that they clear, and in the case of the strippers proper they overrun their workers by thirty times the surface traverse.

The actual direction in which two worker rollers revolve is not an essential in the *theory* of carding, but in order to get any working or combing between two rollers the wires must be inclined point to point, and one must move point first across the points of the other. That is to say, if two rollers A and B (Fig. 15) were rotating point to point, both making 30 ins. surface traverse per second, they would be doing exactly the same amount of combing as if the motion of B (Fig. 16) were increased to 90 ins. per second and A were allowed to retreat heel first in the same direction at its old speed of 30 ins. In both cases the points of B would be running past the points A at 60 ins. per second.

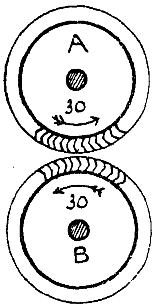


FIG. 15.

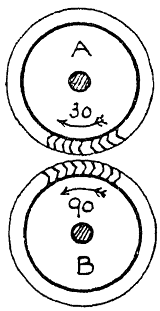


FIG. 16.

It is on this principle that the working power of all rollers must be considered, and in order to get their relative efficiency per inch of width in the machine, the speed must be multiplied by the number of wires per inch linear, counted across the machine. This calculation will show the number of wires moved through any portion of the sliver one inch wide, or the equivalent

number of inches which one pin would travel to do the same amount of work.

Other conditions being equal, the roller which has most points per inch will naturally hold the staples most firmly, and the roller with the fewest points will be doing the combing of the free ends.

Table I. and Fig. 17 show the gearing and dimensions of a Botany worsted card of the type now most generally used. The driving of the swift from the source of power, and the belts from the first swift to the second, are not shown, and they are both taken as running at 100 revolutions. Any alteration of this speed would alter the speeds of every roller in the machine in exactly relative proportion, as every roller is driven from one or other swift.

Rollers and their sizes, as well as chains and chain-wheels, are shown in black, chains being generally on the opposite side of the machine to the belts. Pulleys, belts, and gear-wheels and their sizes are in red, pulley diameters being in inches and gear-wheel sizes in teeth. Wherever the figure 100 occurs first in the calculation in Table I. the sizes of all the wheels and pulleys are given in the line of fractions, but in rollers driven from the first licker, $8\frac{1}{3}$ is taken as the unit, and $\frac{2}{9}$, the speed of the feed-roller, is the unit for the feed-sheet and automatic feed-pan. The speeds calculated in Table I. are used to obtain the results shown in Tables III. and IV.

The clothing suitable for two qualities is shown on Table II. The speeds of a woollen card are introduced to show the difference in the two systems at equivalent stages in the two processes, and their relative efficiency for producing a sliver in which all the fibres are as nearly as possible of their original length.

Everyone must be aware that if long and slightly matted hair be combed rapidly with a fine comb the

TABLE I

SPEEDS OF A BOTANY WORSTED CARD

Roller.	Unit of Speed.	Wheels.	Revolutions per Minute.	Inches per Minute.
A. Swifts . .	100	—	100	—
B. Doffers . .	100	$\times \frac{7 \times 25}{16 \times 250} =$	$4\frac{3}{8}$	$=550$
C. Fancys . .	100	$\times \frac{36}{7} =$	$514\frac{2}{7}$	—
D. Strippers .	100	$\times \frac{36}{13} =$	$276\frac{12}{13}$	—
E. Workers . .	100	$\times \frac{7 \times 25 \times 10}{16 \times 250 \times 13} =$	$3\frac{5}{13}$	—
F. 4th Licker .	100	$\times \frac{12}{12} =$	100	—
G. 3rd ,, . .	100	$\times \frac{12}{24} =$	50	—
H. 2nd ,, . .	100	$\times \frac{12 \times 40}{24 \times 160} =$	$12\frac{1}{2}$	—
J. 1st ,, . .	100	$\times \frac{12 \times 26}{24 \times 156} =$	$8\frac{1}{3}$	—
K. 4th Divider .	$8\frac{1}{3}$	$\times \frac{6}{12} =$	$4\frac{1}{6}$	—
L. 3rd ,, . .	$8\frac{1}{3}$	$\times \frac{6}{13} =$	$3\frac{11}{13}$	—
M. 2nd ,, . .	$8\frac{1}{3}$	$\times \frac{6}{14} =$	$3\frac{4}{7}$	—
N. 1st ,, . .	$8\frac{1}{3}$	$\times \frac{6}{15} =$	$3\frac{1}{3}$	—
O. Feed-Roller .	$8\frac{1}{3}$	$\times \frac{26}{156} \times \frac{26}{156} = \frac{25}{108} =$	say $\frac{2}{5}$	—
P. ,, clearer	$8\frac{1}{3}$	$\times \frac{26}{156} \times \frac{26}{156} \times \frac{74}{28} =$	say $\frac{2}{3}$	—
Q. Feed-Sheet .	$\frac{2}{5}$	$\times \frac{28 \times 2\frac{1}{4} \times 3\frac{1}{7}}{25} = \frac{44}{25}$	—	say $\frac{9}{5}$
R. Pan of Automatic Feed . .	$\frac{2}{5}$	$\times \frac{28 \times 11}{25 \times 13} = \frac{616}{2925}$,	$\frac{2}{5}$ or 1 in $4\frac{1}{2}$ mins.	—
S. Output of Doffing Drawing - off Rollers . .	100	$\times \frac{7 \times 25 \times 3\frac{1}{2} \times 3\frac{1}{7}}{16 \times 20} =$	—	say 601

NOTE.—Many firms now run their cards at higher speeds than those given in the above table; the unit of speed for the swift is often 120, and sometimes even this is exceeded.

teeth will catch in the interlacings and tighten them until they become knots, so that a large number of

TABLE II

CARD CLOTHING TOR TWO QUALITIES OF WORSTED. ALL HARDENED, TEMPERED STEEL WIRE; VULCANISED FILLET

Roller.	Diameter.	For 64s Botany.			For 48 and 50 Crossbred.		
		Wire.	Counts.	Crown.	Wire.	Counts.	Crown.
1st Licker . .	30	18 × 24	30	6	Garnett	—	—
2nd ,, . .	26	29	90	9	24	60	6
3rd ,, . .	26	30	100	10	26	80	8
4th ,, . .	26	32	115	10	30	100	10
1st Divider . .	20	25	70	6	24	60	6
2nd ,, . .	16	29	90	10	26	80	8
3rd ,, . .	16	31	110	10	29	90	9
4th ,, . .	16	32	120	10	31	110	10
1st Swift . .	50	34	130	12	31	110	10
1st ,, workers .	12	34	135	12	32	115	10
1st ,, strippers .	7	31	110	10	27	80	8
1st ,, fancy .	12	31	70	·8	29	60	7
1st Doffer . .	40	35	140	12	32	115	10
Angle Stripper .	7	31	120	10	30	110	10
2nd Swift . .	50	35	150	13½	33	125	12
2nd ,, workers .	12	35	150	13½	34	130	12
2nd ,, strippers .	7	32	115	10	30	90	9
2nd ,, fancy .	12	33	90	8	31	70	7
2nd Doffer . .	40	36	155	14	34	130	12

All wire tinned, up to an including 1st Fancy. Feed-Rollers 6 pins per inch.

Counts and crown are a method of counting which survives from the old hand-carding days.

Counts are the number of points in 5 inches measuring round a roller, and crown is the number of staples (each having two points) in 1 inch across the roller. A swift of 130 counts 12 crown will therefore have $\frac{130}{5}$ or 26 points per inch lengthwise, and 12×2 in 24 points crown, across the roller. The wire number is the size by wire gauge.

hairs will be broken or pulled out by the roots. But if a very coarse comb be first used and drawn many times slowly through the same coat or head of hair

the fibres will be gradually separated, until the work may be finished with a fine comb, and a perfect straightening and separating of every fibre from its neighbour will result with little or no damage either to fibres or locks.

TABLE III

Clothing-Surface Speeds of a Worsted Card

Rollers.	Speeds from Revolutions. Table I.	Diameter.	Inches per Second.	Wire.	Counts.	Crown.
1st Licker . .	$8\frac{1}{3}$	30	13	18/24 diamond point	—	—
2nd ,, . .	$12\frac{1}{2}$	26	17	24	60	6
3rd ,, . .	50	26	68	26	80	8
4th ,, . .	100	26	136	30	100	10
1st Divider .	$3\frac{1}{3}$	20	$3\frac{1}{2}$	24	60	6
2nd ,, . .	$3\frac{4}{7}$	16	3	25	80	8
3rd ,, . .	$3\frac{11}{13}$	16	$3\frac{2}{9}$	29	90	9
4th ,, . .	$4\frac{1}{6}$	16	$3\frac{1}{2}$	31	110	10
1st Swift . .	100	50	262.	31	110	10
1st Workers .	$3\frac{5}{13}$	12	$2\frac{1}{7}$	32	115	10
1st Strippers .	276	7	101	27	80	8
1st Fancy . .	514	12	323	29	60	7
1st Doffer . .	$4\frac{3}{8}$	40	$9\frac{1}{6}$	32	115	10
2nd Swift . .	100	50	262	33	125	12
2nd Workers .	$3\frac{5}{13}$	12	$2\frac{1}{7}$	34	130	12
2nd Stripper .	276	7	101	30	90	9
2nd Fancy .	514	12	323	31	70	7
2nd Doffer .	$4\frac{3}{8}$	40	9	34	130	12

It is exactly in this way that a worsted card should be made to treat the wool if the greatest possible length is to be maintained, and it is in the special arrangements to attain this end that a worsted card differs from a woollen machine.

The table of speeds shows that the feed-rollers move so slowly that they may be considered as holding the wool stationary in both woollen and worsted machines, and the teeth are so far apart that they might be almost

left out of consideration as an opening process—they only traverse $\frac{1}{30}$ inch per second with six teeth per inch. How widely the two processes differ at all working points except the first will be seen from Tables III. and V.

TABLE IV

Relative Efficiency of Working Points in a Worsted Card

No. of Working Points.	Between.	Surface Traverse, Inches per Second.	Direction of Surface Traverse at point of Contact.	Equivalent of Speed.	Points per Inch in One Row.	Combing Efficiency.
1.	1st Licker 1st Divider	13 $3\frac{1}{2}$	opposite	$16\frac{1}{2}$	12	198
2.	2nd Licker 2nd Divider	17 3	,,	20	12	240
3.	3rd Licker 3rd Divider	68 $3\frac{2}{3}$	,,	71	16	1136
4.	4th Licker 4th Divider	136 $3\frac{1}{2}$	,,	139	20	2780
5. 6. 7.	1st Swift 1st Workers	262 2	same	260	20	5200
8.	1st Swift 1st Doffers	262 9	,,	253	20	5060
9. 10. 11.	2nd Swift 2nd Workers	262 2	,,	260	24	6240
12.	2nd Swift 2nd Doffer	262 9	,,	253	24	6072

If we regard the feed-roller simply as the means of supplying wool at a given rate to the first licker, and leave it out of our calculations as an opening process, because the teeth are so coarse that they only serve to separate staple from staple and not fibre from fibre, we find that there is no work done by any of the rollers

of a woollen card (because there is no case of point meeting point) until the unopened staples are rushed by the breast at a speed of 78 inches per second on to the wires of the first worker. As the worker retreats

TABLE V

Speeds of Woollen Card

Roller.	Diameter.	Speed and Gearing.	Revolutions per Minute.	Inches per Second.	Counts and Crown.	Wire.
Licker . .	12	$\frac{100\times12\times9}{30\times12}=$	30	19	—	—
Angle . . .	5	—	340	—	—	—
Breast . .	40	$\frac{100\times12}{32}=$	$37\frac{1}{2}$	78	70/7	26
„ Workers .	8	see 1st Doffer	$6\frac{3}{8}$	$2\frac{1}{2}$	80/8	28
„ Strippers .	5	$\frac{37\frac{1}{2}\times32}{10}=$	120	31	70/7	26
1st Swift . .	50	100	100	262	100/9	31
1st „ Workers	8	see 1st Doffer	$6\frac{3}{8}$	$2\frac{1}{2}$	110/10	30
1st „ Strippers	5	$\frac{100\times34}{10}=$	340	89	80/8	30
1st „ Fancy .	12	$\frac{100\times34}{7}=$	486	305	65/7	30
1st „ Angle Stripper	5	$\frac{100\times34}{10}=$	340	89	80/8	30
1st „ Doffer .	30	$\frac{100\times9\times25}{18\times195}=$	$6\frac{3}{8}$	10	115/10	33
2nd Swift . .	50	100 =	100	262	125/11	35
2nd Swift Workers	8	see 1st Workers	$6\frac{3}{8}$	$2\frac{1}{2}$	125/11	35
2nd „ Strippers	5	see 1st Strippers	340	89	90/9	30
2nd „ Fancy .	12	see 1st Fancy	486	305	75/8	34
2nd Doffer . .	30	see 1st Doffer	$6\frac{3}{8}$	10	130/11	35

3 inches per second in the same direction as the breast there is a working efficiency of 75 inches between the two rollers, and if the breast has fourteen pins per linear inch, we may call the combing efficiency of the three breast workers $75\times14=1{,}050$. The only possible result of such severe treatment is obvious; it is certain

In addition to the relative surface speeds of any two rollers, their size and distance apart directly affect the amount of work they do to wool.

In regard to size, it may be said that the working power of every pair of rollers depends on the space during which they are near enough to do effective work. If we surmise that two rollers begin to operate

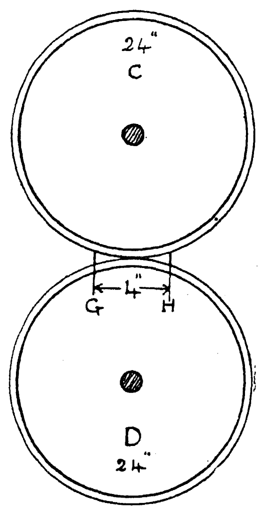


FIG. 18.

the wool as soon as they come within $\frac{3}{8}$-inch of one another, it is clear that they will continue to work for the whole time they are within this distance, and a reference to the figures shows that the surfaces of two 12-inch rollers are within $\frac{3}{8}$-inch of one another for 3 inches, and two 24-inch rollers are within $\frac{3}{8}$-inch of one another for 4 inches, see Fig. 18; and therefore the two 24-inch rollers will do $\frac{8}{6}$ times as much work if the surface speeds and clothing of both are alike. In the diagram the scale has been exaggerated to show the principle more clearly.

Put in another way, we may say, that if a staple were fast on the teeth of B, Fig. 19, at F it will be combed by all the teeth of A between E and F, so that if there be 20 teeth per inch along the circumference it will be combed by 20×3 in a revolution, whereas on G, Fig. 18, it would be combed by $20 \times 4 = 80$. It is, in fact, a case of simple proportion, and one which deserves much greater attention than it receives. It is impossible to say if the working power increases in practice as much as is here shown, for no one could say at what distance the wool begins to be affected by another roller, and if the calculation were based on a distance apart of ½ inch instead of 1 inch the relation of the two calculations would be entirely altered. For this reason no figures have been entered in any of the tables under this head, but there can be no doubt that larger rollers do more work than smaller ones when other things are equal, and the work done between a 40-inch doffer and a 50-inch swift must be severer than that at any other point on a card, even if the action of the fancy (as described on page 87) were left out of account; and if the tests for broken fibres in the tables of page 86 can be taken as a fair average of the breakage which is always going on, some means should be adapted to alleviate the great strain on the wool at that point.

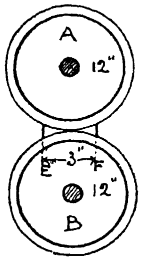


FIG. 19.

Setting.—The knowledge of how to set a card properly is a qualification of the greatest value, not only in a carding overlooker, but to every man who has cards under his care. The best of men make errors, and every manager should be able to supplement the work of his subordinates. Where rollers are kept in the best possible "point" by frequent grinding, they rapidly alter in diameter, and as every alteration makes it

necessary to reset them it is an art of the greatest delicacy which is needed every day.

In France much more attention is given to setting, and the gauge is in constant use, whereas in Yorkshire the eye and ear are often supposed to be good enough for this most delicate operation. The gauge (Fig. 20) very much resembles a closed steel 2-foot rule; but instead of having two blades it has from four to eight, each about $10\frac{1}{2}$ inches long by $1\frac{1}{2}$ inches wide and pivoted at one end, and varying in thickness from $\frac{1}{40}$ to $\frac{1}{80}$ of an inch, or from No. 22 to No. 30 wire gauges.

In a Roubaix firm as soon as a machine has been fettled, and perhaps one or two of the workers replaced by interchangeable duplicates, which are always kept sharp and clean, the overlooker kicks off his wooden sabots and in his thick stockings takes a tour literally over the card, slipping the selected blade from his set of gauges between every working pair of rollers at two or more points along their breadth, and if the gauge fit too tightly or there is too much room at either side a quarter turn is given to the screw which supports the bearing of the worker, to make the adjustment so accurate along the whole working face, that at no point will there be a variation of $\frac{1}{1000}$ inch in the space between the points of the two rollers.

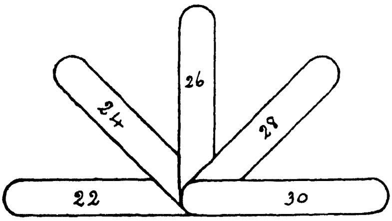


FIG. 20.—CARD SETTING GAUGE

As far as can be seen by a casual observer the machines and clothing used in France strongly resemble our own, but as they obtain better results from short and tender wools, they evidently know how to treat them better than we do, and their superiority can only lie in slight

differences, such as relative speeds, in setting, and in perfection of upkeep. If Yorkshire is to get a fair share in the immense trade in short wools which are now combed in the north of France and exported to this country for hosiery and other purposes, we must learn not only to card these qualities as well as they do, but try to improve on their work, and the first step must be to make our cards suitable in every smallest detail for the difficult work they will have to do.

Setting varies so widely for different qualities that it is impossible to formulate any theory; but it is clear that the early rollers must not be so close together as those farther on in the card, and there should be a fairly definite scale of decrease from the beginning to the end.

The setting of the three workers on each swift may be taken as an illustration, for it is far too common to find them all at one distance from the swift; clearly, if this is the case, the first one will do much more than its share of work, for its position makes it catch nearly all the projecting fibre and do more than half the work, which ought to be equally divided between the three. This will naturally tend to break many of the fibres; whereas, if each worker were set one or two thousandths farther from the swift than the one behind it, each of them would be doing the same amount of work and be equally full of wool, if all three were clothed alike, as is the general practice.

If No. 2 were clothed rather more openly than No. 3, and the first clothed rather more openly than No. 2, the setting would need to be altered slightly in proportion, and the carding would be more gently done in consequence.

In the different boxes of a preparing set the draft of the successive boxes is a most important point, and in a card these various operations are represented by the speeds of each successive pair of working rollers,

as shown in Table III.; but in a card the nature of the operation differs widely from the drafting of a preparing-box, as the wool is not held firmly at any point in a card after it leaves the feed-rollers, and it is therefore quite impossible to calculate any of the individual drafts; and the total draft has very little relation to work done, as it really includes numerous doublings as well as drafts, wherever one roller overruns another point first; and as these doublings are also impossible to calculate, the only figure which is of practical value is the draft between the feed-rollers and the output of the back doffer, which is in inches of surface traverse as $\frac{1}{30}$ to 9, or a total draft for the machine of 270 to 1.

If the carding overlooker is told that his slivers are too thick or too small for the comber, he can alter them, either by altering the speed of his back doffer by the wheel 25 (Fig. 17), or he can alter the weight per minute which the automatic feeder is delivering on to the feed-sheet. The former plan is very seldom adopted, although it would have the great advantage of maintaining the total output of the card at its greatest amount, and in practice alteration is generally made at the feed end, the *length* of sliver turned out remaining constant and the weight being varied according to the size of sliver required.

Theories of Carding.—As was mentioned on page 66, many theories have been propounded as to the manner in which wool passes through a carding-machine. For example, the arrangements of a Holden comb are said to be based on the idea that, on account of the serrations of the wool and the theory of moving hairs already mentioned, all the hairs come out of a card arranged in one direction, no matter how they are fed up to the feed-rollers; that is to say, all the hairs in a carded silver are supposed to be root end first or point first—

probably the former. Unfortunately, this theory has no support in practice; it was founded only on results, and no proof ever seems to have been attempted prior to the experiment tabulated on page 86.

In order to clear up this matter once for all, the writer sorted a few pounds of well-defined hog wool, taking them carefully staple by staple and arranging them in bunches, with all the roots at one end and all the points at the other. In this form the point half of the wool was dyed a vivid crimson, the root half remaining white. When dry, they were taken to the card. Here the sample was divided into three lots, and each was put up to the feed-rollers by hand in different positions.

In experiment *A* every fibre went through the feed-rollers point first.

In *B* the staples lay in all directions to imitate the result of a machine feed.

In *C* every fibre went up root first.

In every lot the resulting sliver was tested at three widely separated places, 100 fibres being counted in each case, the similarity of the results being nothing short of extraordinary. The fibres which are counted as broken are those in which the white portion had disappeared, and as only red fibres were counted, the opposite ends of the same fibre could not be counted twice, and the number of breakages, not the number of broken pieces, was ascertained. In addition to this estimation, the machine was stopped in the middle of every test, and wool was taken from the first and second swift workers, care being taken to note which end came off first. The result is a clear refutation of any and all theories which claim that wool fibres take any special position in a carded sliver; and as there is no chance for fibres to rearrange themselves in after processes it is clear that in all tops fibres occur indiscriminately (it

may almost be said, alternately) root and point first. The bearing of this question on the theory of the Holden and Noble combs will be dealt with further in subsequent chapters.

In this experiment it is impossible to say what would be the result if every staple were held by the card clothing either by its extreme point or extreme root, though, even in that case, it is doubtful if they would come out in the same order in the sliver.

In the six rollers of the card the staples were mostly caught by the wire, not far from the middle; very few, indeed, were held at either end, and when they lie on the licker in this position (Fig. 22) they are caught by the divider in exactly the opposite way to that which would be the case if they were securely held by the point, as in Fig. 21.

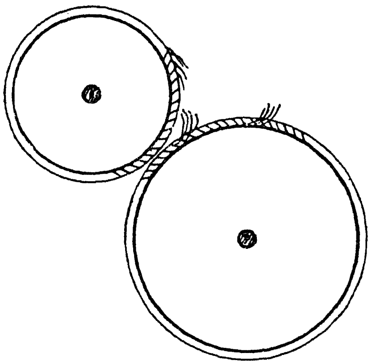


FIG. 21.

Anyone who will take the trouble to arrange a few pounds of wool point first on the feed-sheet, will find that, on the second divider, there are almost equal quantities point and root first; and as each pair of working rollers repeats the process, it is clear that before the wool reaches the first swift the fibres will be so completely disarranged that any relation of root to root, or root to point, which they had on the feed-sheet, will be quite indistinguishable.

If this is the case, where all the fibres are going up point first or root first, with a distinct tendency to be caught on the licker by the tip which comes first through the feed-rollers, the blending must be still more com-

plete when they are fed indiscriminately by a machine; because every staple which lies across the feed-rollers will be caught very near its middle by the points of the licker.

The main lesson to be learned from the experiment is very clear. Fibres will be found in nearly equal numbers in a carded sliver, point and root first, no matter how they may have been arranged on the feed-sheet.

The lessons from the numbers of broken and looped fibres are not quite so decisive; but two points may safely be inferred from the averages in Table VI., where the results of *A*, *B*, and *C* are taken together. As there are more broken fibres in the finished sliver than in the wool from the workers, and a few more from the second worker than from the first, it seems that most of the breakages occur between the doffers and the swifts, and many more between the second swift and doffer, than at the first.

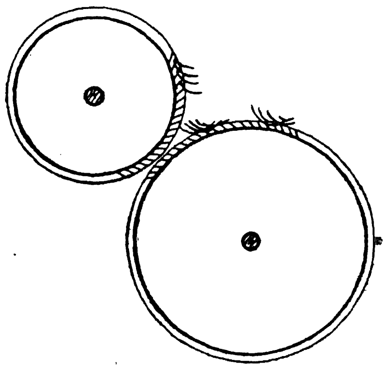


FIG. 22.

The number of looped fibres is more plainly attributable to the doffers, and bears out the statement made in reference to hand cards that, though the wool may be perfectly straight whilst on the card, the act of removing it again rumples and curls it. If a card be stopped when it is full of wool it will be seen that the great speed of the swift lashes the wool from the fourth licker deep and nearly straight into the wire of the swift, so that each worker can only deal with a small portion of what is travelling forward on the swift.

TABLE VI

Tests Made on a Four-Licker Worsted Card
Wool with Points dyed Crimson

A. *Fibres fed to Feed-Rollers point first.*

	Fibres in Carded Sliver.				Test from	
	Test 1.	Test 2.	Test 3.	Average.	1st Worker.	2nd Worker.
Point First . .	31	33	26	30	46	41
Root First . .	39	31	34	$34\frac{2}{3}$	41	36
Looped . .	3	9	29	$7\frac{2}{3}$	—	7
Broken . .	27	27	11	$27\frac{2}{3}$	13	16
	100	100	100	100	100	100

B. *Fibres fed to Feed-Rollers blended.*

	Fibres in Carded Sliver.				Test from	
	Test 1.	Test 2.	Test 3.	Average.	1st Worker.	2nd Worker.
Point First . .	40	39	35	38	48	54
Root First . .	37	46	39	$40\frac{2}{3}$	48	41
Looped . .	5	4	10	$6\frac{1}{3}$	—	1
Broken . .	18	11	16	15	4	4
	100	100	100	100	100	100

C. *Fibres fed to Feed-Rollers root first.*

	Fibres in Carded Sliver.				Test from	
	Test 1.	Test 2.	Test 3.	Average.	1st Worker.	2nd Worker.
Point First . .	41	44	38	41	—	48
Root First . .	45	42	43	$43\frac{1}{3}$	—	43
Looped . .	1	1	3	$1\frac{2}{3}$	—	3
Broken . .	13	13	16	14	—	6
	100	100	100	100	—	100

Total—	Average.	1st Worker.	2nd Worker.
Point First	$36\frac{1}{3}$	47	$47\frac{2}{3}$
Root First	$39\frac{5}{9}$	$44\frac{1}{2}$	40
Looped	$5\frac{2}{9}$	—	$3\frac{2}{3}$
Broken	$18\frac{8}{9}$	$8\frac{1}{2}$	$8\frac{2}{3}$
	100	100	100

Where the swift overruns the doffer it is quite different, for the fancy brushes up the ends of the fibres, so that every one must be affected by the doffer; and as the doffer has more points per inch than the swift, it holds practically all the fibres, whilst the wire of the swift is torn through all that part of the wool which is still below its points: and though the wool is fairly well opened by this time, the treatment is the severest it has received up to this point.

The looping is accounted for in a slightly different manner. Whilst the fibre was lying deep in the wire of the swift, it was unaffected by the air, but after it has been brushed up by the fancy the resistance of the air retards the points to a considerable extent, so that many are driven looped on to the wire of the doffer, and though they are, for the most part, straightened by the angle stripper and second swift, a good many of them go forward doubled up. Probably as many loops are made at the first doffer as at the second, but the second doffer has no following roller to straighten any of them again; and though this crumpling action is a positive advantage in the woollen trade, because it makes the sliver bulky, it is a very serious detriment in worsteds, and has to be counteracted, as far as possible, by three gilling processes before the wool goes to the comb.

It was a common saying amongst carding overlookers of the old school that there was a huge fortune for the man who would first take wool from the swift in its straight condition without rumpling it as all doffers do; and though no one has yet claimed the reward, there is no doubt that if the thing could be done, it would immensely increase the value of the carded sliver by greatly reducing the amount of noil made at the comb, and increasing the average length of fibres in the top.

Heating.—It is a well accepted fact that a good deal of heat is necessary to obtain the most satisfactory results in carding, but it is not very clear exactly what effect the heat has on the structure of individual fibres; the fact must be taken as it stands, quite apart from any theory on the subject.

The most satisfactory work is done at an air temperature of over 75° Fahrenheit, but any heat between 75° and 95° seems to be good, and if it were not for the discomfort to operatives it is probable that temperatures of 85° and 90° would be much more often adopted. Sometimes when the first lickers in are made of iron they are themselves heated by steam; but the more general method is to have three or more "cannons" or coils of steam pipes under each card, so arranged that the ascending warm air has every opportunity of affecting the wool as it passes through the machine.

Doffing.—The method by which wool is removed from the doffer is so simple that very little explanation is necessary. At the point where the doffer is stripped by the doffing motion the wires are pointing downwards, and the doffing comb or plate, which is a smooth steel comb with very short teeth (from 16 to 20 per inch), rises and falls very fast, as near as possible to the wire of the roller. The direction of the points of the doffer, and the pull of the drawing-off rollers, prevent the wool from rising with the comb on its up stroke, and the doffing comb may be said simply to push the wool down out of the wire, ready to be drawn away by the drawing-off rollers. When the wires of the doffer are very sharp and smooth, a free and open quality of wool will come away from the doffer with very little help from the comb, and in some cases it may be seen to leave the doffer some inches before it can be touched by the comb.

The arrangements for driving the motion are so numerous and simple that it is of no use to describe them in detail. They may be all classed under two types—those in which the comb simply rises and falls $1\frac{1}{2}$ or 2 inches in the arc of a circle (Fig. 23), and those in which the comb draws away from the wire at the bottom of the stroke and is farther away from the doffer on the up stroke than on the down stroke. Of this type there are also variations, but most of them are carried on an excentric 1 (Fig. 24) and have an arm or lever attached by a joint 2 to the shackle 3. If the distance from the comb 4 to the centre 1 be double the length of the arm 1 to 2, and if the excentric have a stroke of half-an-inch, the comb will have an up and down movement of $1\frac{1}{2}$ inches, and if it be $\frac{1}{16}$ from the wire of the doffer 5 (Fig. 25), on the down stroke it will be $\frac{9}{16}$ away as it rises (Fig. 24).

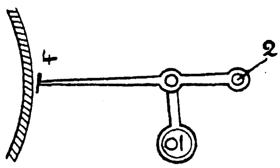


FIG. 23.

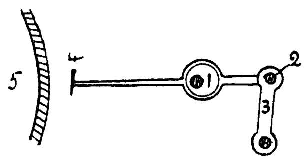


FIG. 24.

Opinions differ widely as to which is the better form. The excentric motion certainly helps to draw the wool away from the wire after it has loosened it, but, on the other hand, it travels in a kind of elliptical orbit and is not so close to the doffer for the same proportion of the down stroke as is the comb in the simpler type (Fig. 23).

Automatic Feed.—The object of an automatic feed, as pointed out on page 65, is to ensure that every yard of sliver turned out by the card shall be of exactly the same weight—in other words, that the sliver shall always be of exactly the same thickness. When wool

was fed by hand on to the feed-sheet of a card, it naturally followed that the weight of the sliver varied from time to time, because it was impossible for any feeder however expert to judge by feel, or by any other method, if there were just the right weight of wool on the feed-sheet.

Carders who were particular then began to consider ways and means to render the weight of their sliver more constant, and some of them marked out the lattice into divisions, each, say, 12 inches long. A scale to weigh the wool was placed by each feed-sheet, and just as one mark was passing the feed-rollers, half-a-pound or other weight of wool was taken from the scale and spread over a division of the feed-sheet. This system is only accurate where great care is used, but it introduced the principle on which the automatic feeding-machines are constructed; they weigh out a given weight of wool on to a given length of feed-sheet, and are so arranged that the weight can easily be altered as required for different qualities of wool. To do work of this kind it is natural that the mechanism is very delicate and too intricate to be explained clearly in print alone, but the principal parts of the machine when stripped of their driving gear can easily be understood if taken one by one.

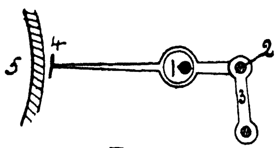


FIG. 25.

The feed-roller as shown on Table I. moves two-ninths of a revolution per minute, and is geared to the feed-sheet F (Figs. 17 and 26) by wheels 25 and 28,

$$\therefore \text{ the feed-sheet moves } \frac{2}{9}\times\frac{28}{25}\times 2\tfrac{1}{4}\times\frac{22}{7}=\frac{9}{5} \text{ inches}$$

per minute. But the cam C (Fig. 26), which opens the pan P by means of lever L, is also driven direct from the feed-roller through the same wheels 25 and 28, and

the chain over wheels 11 and 13. The two wheels which drive the cam C are equal in size $\therefore \frac{2}{9} \times \frac{28 \times 11}{25 \times 13} = \frac{2}{9}$. This shows that the pan opens once in every $4\frac{1}{2}$ minutes —that is $\frac{5}{9} \times \frac{9}{2}$ or once every time the sheet has moved $8\frac{1}{10}$ inches, and if the pan always contains half-a-pound of wool, it follows that every 8 inches of feed-sheet must always be covered by half-a-pound of wool. In this the whole principle of the machine is embodied. The mechanism for filling the pan is quite simple. The sheet G is covered with pins, and when it is running they carry the wool up from the hopper H over into the pan. The sheet is started by the lever L as soon as the pan closes at every revolution, and the sheet continues to run until there is enough wool in the pan to lift the weight W. When W rises it touches a trigger and stops the supply of wool by an intricate arrangement, which stops the pin sheet at the exact moment that the pan has received the proper weight of wool. The other movements on the machine are simply arranged to distribute the wool evenly in the pan, which extends the full width of the machine, and to press the wool up to its proper place after it has fallen into the feed-sheet.

Machines made by different makers vary very much in their design, but they are all arranged so that a definite weight of wool goes through the feed-rollers at every revolution, and in all of them this is regulated by the number of inches moved by the feed-sheet for every charge of wool which is delivered by the pan.

If well looked after the machines have very few disadvantages; but in the old design there was a distinct tendency for the ascending sheet G to turn the wool over and over in the hopper, until it was rolled and somewhat entangled. If this rolling is guarded against the work done is in no way worse than hand

feeding, and the resulting sliver is infinitely more regular.

In Fig. 26 the belt from K to M and the clutch gear which drives the sheet from M are not shown.

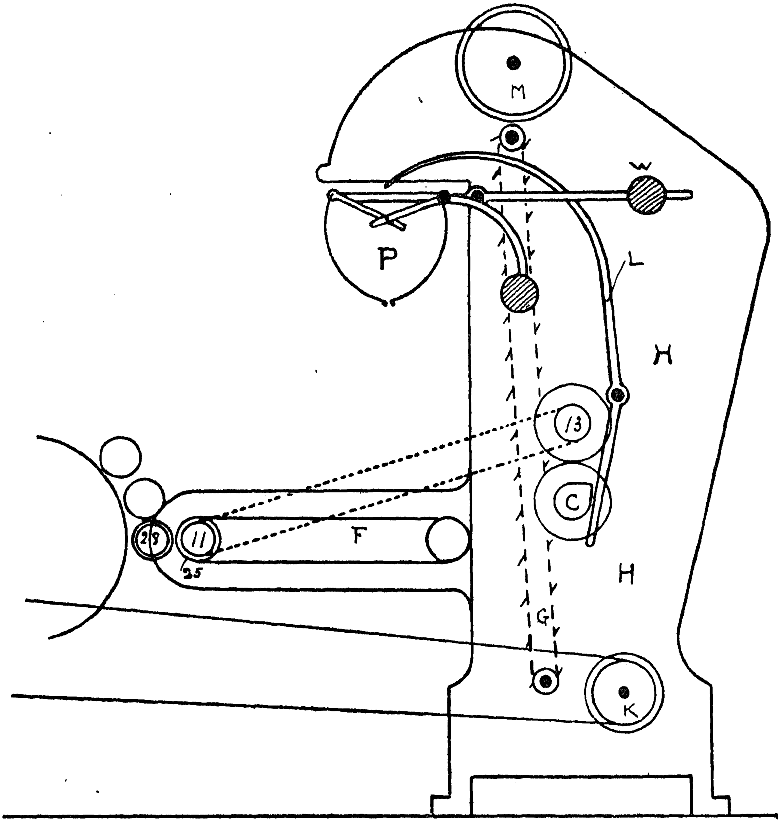


FIG. 26.—AUTOMATIC FEEDING MACHINE.

Burring.—There are few things which cause more annoyance to spinners and manufacturers than the seeds of a plant, native to Australia, which are known to everyone in the trade as burrs. Their natural shape, as seen in the unwashed fleece, is that of a very small

pea, but they are soft, and are built in spirals of prickly fibres, which are capable of unwinding to such an extent that after carding, each burr seed may produce several inches of the thin spiked fibres which are so injurious both in spinning and weaving. When the seeds are ripe they stick to the wool of any sheep which passes the plant on which they are growing; and they adhere through every process until they are forcibly removed or destroyed. Burrs now occur in small numbers in almost every class of wool, so that almost all carding-machines are provided with rollers for removing them. Any number of burr rollers up to six are placed above the lickers and dividers as shown in Fig. 17, so that the burrs may be knocked out whole, before they are opened by the carding process. Each roller is set as shown in Fig. 27, with its blades always revolving against the points of the card wire. In this position the draught caused by the revolution of the beater drives the wool on to the wire, whilst the burrs are hit by the wings of the beater and thrown forcibly into the tin provided to catch them. If the roller revolved in the opposite direction, it would tend to lift the wool as well as the burrs from the card. With wool which only contains a medium quantity of burrs this process is very efficient; but in cases where it is essential to have every atom of burr fibre removed, or where the burrs are very numerous, other methods are adopted.

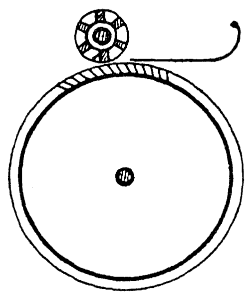


FIG. 27.

The oldest machine for this purpose consisted of two heavy metal rollers, turned up very true and fixed so rigidly in a frame that they were always about one-hundredth of an inch apart. Through this very narrow

space the wool fibres could go with impunity, but any burr was crushed to pieces in passing. When such rollers are used before carding the locks of wool are apt to go through the rollers in lumps so thick that they, like the burrs, are cut to pieces, and to insure the wool passing the rollers in a uniformly thin film, the rollers have been used both after and in the middle of the carding process. Probably when placed in the middle of the card they do their work the best, for the rollers which precede them open out the staples into a film of uniform density, so that nothing but the burrs can be crushed by the crushing rollers.

Most of the broken fragments of vegetable matter fall on to the floor as the wool passes over the remaining rollers of the carding-machine. Any pieces which can be found in the carding sliver after this process are very short and can always be taken out in the combing, so that after this process tops can be guaranteed free from all vegetable fibre unless there be hemp or manilla present, due to carelessness in packing or sorting.

Whilst speaking of this subject, it may be well to call attention to the immense number of fibres which result from one or two inches of hemp twine, after it has been pulled to pieces by a carding-machine. Hemp is impervious to most of the dyes used for wools, and therefore where such dyes are used, each fibre will show as a tiny stripe when the piece is dyed and finished.

The latest patent for removing burrs consists of a roller covered with square-toothed garnet wire, so finely set that at first sight the roller appears to be solid. The fact is that the wires are so close to one another that the wool can just get down between them, but the burrs cannot do so. The exact position of this roller in the card does not affect the principle of its working, its usual position being near to the feed-rollers. Wherever it may be placed, a burr beater or

scraper is always fixed close above it, the blades coming within, say, one-fiftieth of an inch of the garnet wire, so that they literally scrape away every burr which comes to them, whilst the fibres, held fast between the wires, are dragged away from the burrs to the carding rollers which follow. This machine is said to do wonderfully good work, and is at work in many places in Bradford.

The fourth system of taking out burrs by carbonising does not properly come within the scope of a comber, although it is very frequently used in the woollen trade, and, doubtless, a great deal of wool which is used for worsteds is carbonised before it comes to the comber. The best carbonised wool is that which is treated before it is removed from the skins, but in the great majority of cases it is treated after scouring. It is, in fact, necessary that all impurities should first be removed. The wool is then put into a solution of sulphuric acid in clean water (of a strength varying from 6 to 10 Baume) for twenty to thirty minutes, when it is taken out and whizzed or left to drain in such a place that the acid can return to the steeping tank. When nearly dry, the wool is placed in an oven at 45° C. until it is quite dry, when the temperature may be raised to 100° C. until all vegetable matter is thoroughly disintegrated. The wool and burrs are then crushed between heavy iron rollers. After this treatment all that remains of the burrs and shives will fall out in the carding. The only drawback is the effect of the acid on the fibre. Theoretically, it does no harm if the acid never exceeds 12° Baume in density; but, where wool has to be spun to fine counts, it is found that either the acid or the baking, or both, leave fine wool with so much harsher feel that its spinning power is sometimes affected, and wool which is known to be carbonised is not as valuable as uncarbonised.

Transport.—In the old days almost every card was fitted with a balling head, or the slivers from two cards were at times run into one head. In either case the ball was so large and loosely built that it was quickly knocked out of shape and very difficult to work. To make the carding easier to handle six or eight ends were run together, without any draft, through a doubling-box, which was, in reality, little more than a second balling head, and the sliver in the ball it made was eight times the thickness and one-fourth the length of that in a carding ball. These balls were so large and difficult to handle that they were often lifted by a strand of sliver, and so torn. Six or eight balls made up one creel in the backwash, and, as the sliver was very thick and relatively short, whenever an end had been broken or ran out, a piecing was made which added one-sixth to the total bulk of the slivers going up to the fallers, and making a joint so thick that even the strong faller gills could not clear it, but usually left it as a lump in the gilled sliver. Working with a creel so arranged, and a draft of 5 on the gill-box, there would be 600 yards of backwashed sliver produced free from piecing, and then would come six piecings, each bad enough to be classed as a serious fault.

In all the best combing plants every card is now fitted with a can coiler, and all cans are taken direct to the backwash, and run up to the machine without having the slivers touched in the interval. 48 or 50 single slivers will be required to equal the 6 balls of 8 slivers each. Each can will hold 15 lbs., or 960 yards, and with a full new set and a draft of 5 this will make 4,800 yards of backwash sliver free from any piecing. Then each can will run out at a slightly different time, and each piecing will add only $\frac{1}{50}$ to the total bulk of the slivers, and make a joint which will be invisible after once gilling.

Grinding has three important uses—

1. To make the wire on the rollers perfectly true—that is to say, that the end of every wire shall be absolutely equidistant from the axis on which the cylinder revolves.
2. To keep every wire sharp, so that it will catch the wool fibres readily and easily.
3. To keep the points smooth, so that with equal facility the fibres may be taken again from the roller.

The first head raises the much-debated question of wood *versus* metal rollers, and as there are still many people who contend that well-built wooden rollers can be kept true, and that the clothing has more spring and lasts longer on wood than on iron, no hard-and-fast rule can be laid down.

On the other hand, everyone must admit that wood is affected by moisture and heat, and as both these influences are always present when carding is going on, iron and steel rollers have the great advantage that they have no tendency to alter on account of moisture, and their expansion with alteration of temperature is infinitesimal and absolutely uniform in every direction; whilst, if carelessly treated by subjection to excessive changes of temperature or humidity, the best of wood and the most scientific construction will not prevent some alteration in a wooden roller.

Those built of lags running from end to end of the roller at right angles to the circumference are most easily affected, because wood swells most across the grain and increases very little in length when damp. This type should only be used for rollers of small diameter.

Swifts and doffers, on the other hand, are often built up of very small sections, which are glued, nailed, and clamped together, the length of the grain being parallel

with the circumference. Here there is little tendency to swell outwards from the axis of the roller, and the swelling in length is of no great importance, and is counteracted by the cramp bolts which run from end to end of the roller.

Wooden rollers have the advantage that the clothing can be secured by tacks driven in at any point. Iron rollers have to be bored at suitable intervals and plugged

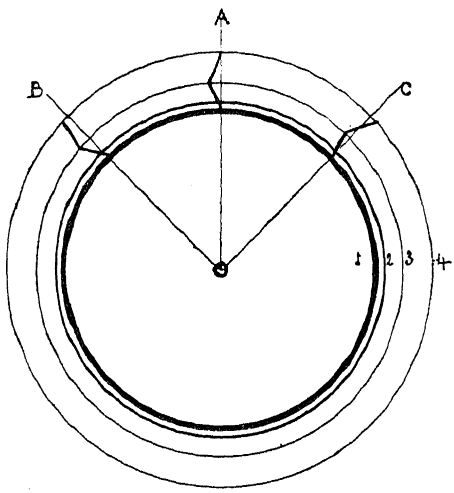


FIG. 28.

with wood, and the tacks must be driven into these plugs.

The correct angle at which the wires of the card clothing should stand is shown in Fig. 28. The inner circle 1 represents the circumference of the wood or iron cylinder. The space 1-2 is the foundation of the clothing. Line 3 is the correct place for the bend. Line 4 is extremity of the wires after grinding. The wire on the radial line A is in the correct position.

When working, the wires have a tendency to bend backwards. They must be so pricked in the clothing

that whichever way they bend, their points must be at the greatest distance from the centre of the roller. When at rest this position is on the radial lines. Whichever way A is bent in the foundation its point comes within the circle 4.

C, on the other hand, is very badly set, because when bent back its point would be outside circle 4 and would touch the roller with which it was working. The wire C would at once lose its point and would damage or blunt the other roller. Wire set like B is safe, but a very slight backward movement would take it so far from the line 4 that it would be of little use in working.

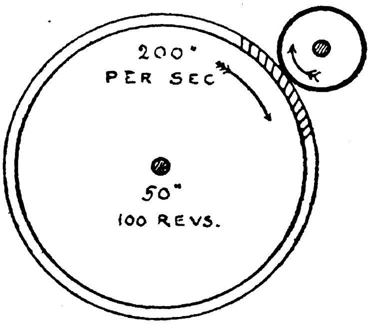


FIG. 29.

When a large wooden roller (*i.e.* a swift or doffer) is to be clothed it is first turned up in its own bearings until it runs absolutely true. The clothing is then wound on very tightly, the drag being kept absolutely uniform by means of a machine, whilst the roller is turned very slowly by gearing. In spite of all the care that is taken in the making and winding on of the clothing, the pitch at which the wire stands is apt to vary slightly in places, or the wire itself may not bend with equal uniformity all along the surface, so that the roller never runs absolutely true when clothed, and, to make it true, it must be ground, the longest wires being ground away until they are exactly equal in length to the shortest.

Workers, strippers, and fancies are taken to a special frame to be ground (Fig. 30), but a swift or doffer will always be run in its own bearings, the clothing in every case *travelling heel first* at a surface speed of 200 to

250 inches per second (100 revolutions per minute for a 50-inch cylinder). At the point of contact the surface of the emery roller moves exactly opposite to that of the swift (Fig. 29).

An emery roller, about the same size as a worker (10 to 12 inches), is put into a pair of worker bearings, which are so adjusted by fine screws S that at first it only just touches the "proudest" points of the wire. If the work is not done very gently the wires will be

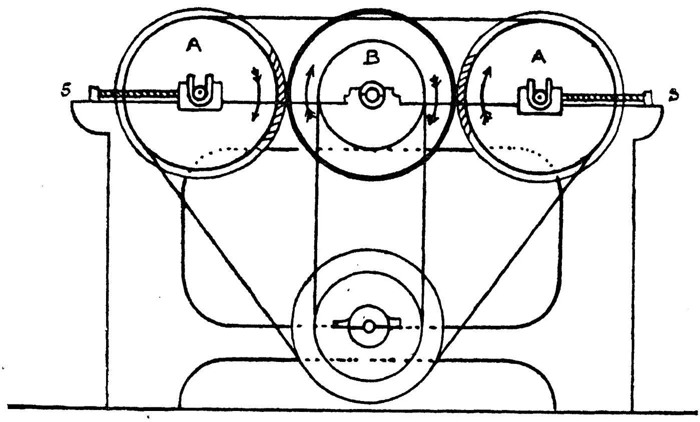


FIG. 30.—GRINDING FRAME.

bent down instead of being ground away to the requisite length, and as soon as the roller begins to do its work, running point first, the wires will return to their original position and make very bad work by touching or taking the point off other rollers, which they ought just to clear.

As grinding continues and the longest wires have been somewhat shortened, the emery roller whilst continuing to revolve is moved very slightly nearer to the swift, and in this manner the grinding is continued until all the wire is of uniform length, and the emery roller touches the wire with equal pressure during the complete rotation.

In France grinding receives greater attention than is general in this country, and, as has already been inferred, it is common for cards to have several spare workers, if not a complete set, so that they can be ground whilst the machine is running, and a perfect roller can at any time be slipped into the place of any one which has lost its point from any cause.

The method usually adopted in this country is to stop a machine every three or four days, and whilst the swifts and larger rollers are being ground in their own places all the workers and smaller rollers are taken to a grinding frame.

The frame is made to take a clothed roller A on either

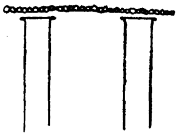


FIG. 31.

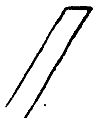


FIG. 32.

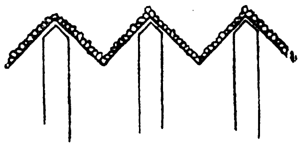


FIG. 33.

side of the emery roller B, revolving in the direction shown (Fig. 30), the workers being driven heel first with a surface traverse of about 200 inches per second, exactly opposite to that of the emery roller at the point of contact.

If the emery used on the roller be very fine in grain, the resulting point on the wires would be quite square (Fig. 31) when seen from front or back, with a diamond or tool point seen sideways (Fig. 32).

In practice this is not very satisfactory, for when any piece of metal is filed or ground squarely across the grain a slight lip or curl at the edge almost invariably results, and though it is so small as to be quite invisible on the wire, it is sufficient to affect the fine fibres in course of carding and cause them to stick instead of leaving the roller freely.

Some method had to be devised to remove this rough edge, and it was found that fine emery laid on the roller in grooves (Fig. 33), or very coarse grained emery (Fig. 34), had the same effect as a file held diagonally,

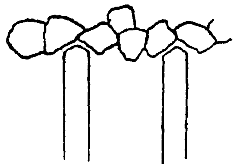


FIG. 34.

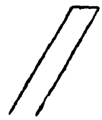


FIG. 35.

the wire being ground to a knife edge instead of a square point and having the same tool point when seen from the side; so that, if greatly magnified, the surface of the roller and the points of the wires would be illustrated by Figs. 33, 34, and 35 and a point produced without any rough edges.

CHAPTER V

PREPARING

THERE are no two processes in the trade for attaining the same end which differ so widely in principle and practice as do carding and preparing, and yet the results are so similar that in a medium quality it is doubtful if an expert could tell whether a top had been carded or prepared. Preparing is only suitable for long wool, and carding for shorter sorts. Opinions differ as to the exact qualities and lengths of medium wool which give the best results carded or prepared.

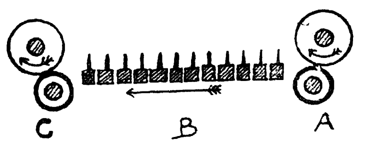


FIG. 36.

Preparing, like all other gilling, is a continuous combing process. The essential parts of each machine are very simple, and for consideration of principles they are best regarded quite apart from the mechanism which moves them. Every gill-box must have back rollers, front rollers, and fallers; the action of the machine depends entirely upon the relative speeds of these three parts (Fig. 36). The motion of the rollers is rotary, and that of the fallers is horizontal, but all three move the wool forward in the same direction. To compare their action we will try an experiment with each in turn. Suppose only the back rollers A to be running with a piece of tape between them, they will move, say, one yard in a minute, or other unit of time. With the fallers B running and the back and front top rollers removed, the pins would move 6 inches in the

same time, whilst the front rollers C alone would move no less than 36 inches. This relative amount of delivery is called draft, and the proportions taken are suitable for a first box. Every consecutive box in a set would vary in the size of its parts and their relative speeds, but in all gill-boxes the front rollers move faster than the fallers, and the fallers than the back roller. For the sake of brevity, the relation of the fallers to the back roller will be termed the back draft; that of the front rollers to the fallers will be termed the front draft; and that of the front rollers to the back roller will be termed the total draft.

Tabulating the above figures, we find—

Back rollers deliver 1 yard per $1\frac{1}{2}$ mins. Fallers deliver 6 yards per $1\frac{1}{2}$ mins.	therefore the back draft is 6 to 1;
Front rollers deliver 36 yards per $1\frac{1}{2}$ mins.	therefore the front draft is 6 to 1;

and the total draft is 36 to 1, which makes it clear at the outset that the total draft is the multiple and not the sum of the back and front drafts, and this is further proved in the gearing calculations (pages 106 and 114).

In all Botany boxes, however, the back drafts are so low that often there is very little difference between the sum and the multiple of the two drafts, and hence the principle is not always clearly understood; for instance, such a box might have—

Back draft.		Front draft.		Total.
$1\frac{1}{4}$	$\times$	4	$=$	5, but $1\frac{1}{4}+4=5\frac{1}{4}$—showing a plus error of only $\frac{1}{4}$
$1\frac{1}{2}$	$\times$	4	$=$	6, but $1\frac{1}{2}+4=5\frac{1}{2}$—minus error of only $\frac{1}{2}$

As can be seen from Table VII., this is never the case in preparing where no two boxes are alike. The

dimensions given are from a set of Preparing Boxes made in 1903 for long English wool, and the drafts are those given on the machine maker's quotation; in practice they would, of course, be varied, the gearings used by different firms for the same quality being so dissimilar that it is impossible to formulate theories in respect of them. In the calculations, wheels have been used to make the fractions simple, which might not be used in practice, and it is intended that the figures should show the method of working out drafts on all boxes, not that they should be the actual figures adopted by any particular firm.

For medium qualities the sizes of the boxes would be the same, but the drafts would be slightly shorter, and the pins of the fallers finer and closer together.

Table VII. shows that the back draft is the highest in the first box and steadily decreases as the wool advances, so that it has been reduced to $2\frac{1}{4}$ at the back-wash box.

The total draft varies slightly more than the back draft, whilst the front draft only alters from 6 to 4 throughout the whole ten processes.

Some years ago Messrs. Clough & Kelly patented a machine to increase the drafting power of every box, and so reduce the number of boxes in a set. Each box had two sets of screws and two sets of fallers, B and C (Fig. 37), in the same plane, one behind the other. The speed of all gill-boxes is, however, limited by the number of fallers that can safely be dropped per minute. 120 is the maximum for $1\frac{1}{4}$ inch fallers, so $120 \times 1\frac{1}{4}$ must be the unit of output for the second screw C. There are three drafts of 4 to 1 each in the box, therefore the front rollers would turn out 24 yards in $1\frac{1}{2}$ minutes, and the first bed of fallers B would only drop $\frac{1}{4}$ of 120, or 30 per minute.

TABLE VII

Set of Long Wool Preparing Backwash Finishing Gill-Boxes

	Back Rollers.			Front Rollers.			Pitch of Screw.	Ratch.	Drafts.		
	Diameter.		Flutes per Inch.	Diameter.		Flutes per Inch.			Back.	Front.	Total.
	Top.	Bottom.		Top.	Bottom.						
1st Sheeter . . .	6	$3\frac{1}{2}$	4	5	$3\frac{1}{2}$	3	$1\frac{1}{4}$	24	6	6	36
2nd ,, . . .	6	$3\frac{1}{2}$	4	5	$3\frac{1}{2}$	3	$1\frac{1}{8}$	24	6	6	36
3rd Can box . .	6	3	4	5	3	4	1	23	4	4	16
4th ,, ,, . . .	5	3	5	5	3	4	$\frac{7}{8}$	22	3	4	12
5th ,, ,, . . .	$4\frac{1}{2}$	3	5	5	$2\frac{1}{2}$	5	$\frac{3}{4}$	21	$2\frac{1}{2}$	4	10
6th after Backwash .	$4\frac{1}{2}$	3	5	5	$2\frac{1}{2}$	5	$\frac{5}{8}$	20	$2\frac{1}{4}$	4	9
7th ,, ,, . .	4	3	5	5	$2\frac{1}{2}$	5	$\frac{5}{8}$	20	$2\frac{1}{4}$	4	9
8th ,, ,, . .	4	3	5	5	$2\frac{1}{2}$	5	$\frac{5}{8}$	20	$2\frac{1}{4}$	4	9
2 Finishing-boxes .	3	$2\frac{1}{2}$	6	4	$2\frac{1}{2}$	6	$\frac{9}{16}$	20	$2\frac{1}{4}$	4	9

TABLE VIII

Particulars of Fallers

	Pitch of Screw.	Fallers.		Pins.			Pinned Over.	Fallers Dropping per Min.
		Up.	Down.	Rows.	Per Inch.	Length.		
1st Sheeter .	$1\frac{1}{4}$	14	6	2	2	$1\frac{3}{4}$-2 ins.	16	120
2nd ,, . .	$1\frac{1}{8}$	14	6	2	$3\frac{1}{2}$	$1\frac{3}{4}$-$1\frac{7}{8}$,,	16	130
3rd Can box .	1	14	6	2	$4\frac{1}{2}$	$1\frac{3}{4}$-$1\frac{7}{8}$,,	16	140
4th ,, ,, .	$\frac{7}{8}$	16	7	2	5	$1\frac{3}{4}$-$1\frac{7}{8}$,,	16	150
5th ,, ,, .	$\frac{3}{4}$	16	7	2	6	$1\frac{1}{4}$-$1\frac{3}{8}$,,	16	180
6th Backwash .	$\frac{5}{8}$	16	7	1	6	$1\frac{1}{4}$-$1\frac{3}{8}$,,	16	190
7th Can box .	$\frac{5}{8}$	16	7	2	8	$1\frac{1}{4}$-$1\frac{3}{8}$,,	16	200
8th ,, ,, .	$\frac{5}{8}$	16	7	2	8	$1\frac{1}{4}$-$1\frac{3}{8}$,,	16	200 double thread screws
9th Finisher .	$\frac{9}{16}$	16	7	2	12	$1\frac{1}{8}$-$1\frac{3}{16}$,,	16	300
10th ,, .	$\frac{9}{16}$	16	7	2	14	$1\frac{1}{8}$-$1\frac{3}{16}$,,	16	300

Tabulated, these figures mean that—

Back rollers,	A,	output is	$13\frac{1}{2}$ ins.	per	$1\frac{1}{2}$ mins.
First fallers,	B,	,, ,,	$1\frac{1}{2}$ yards	,,	$1\frac{1}{2}$,,
Second fallers,	C,	,, ,,	6 ,,	,,	$1\frac{1}{2}$,,
Front rollers,	D,	,, ,,	24 ,,	,,	$1\frac{1}{2}$,,

We will suppose that in both types of box the first fallers fix the amount of load fed up: in that case the weight coming through the back rollers could be no more with two sets of fallers than with one, and as the speed of the back roller is only $\frac{1}{3}$ of the speed of the simple box, the total output will be relatively small. The box has its advantages in some trades, but compared with the ordinary boxes they are now only made in very small numbers.

All wool which is to be prepared is straightened out by hand before it is put on to the feed-sheet D of the first box (Fig. 38), where all the staples are laid by the operative as nearly parallel as possible, and at

right angles to the back rollers. In this way the wool goes through the rollers A, and the fallers rise with their pins right through the staples. As soon as each faller rises it moves steadily away from the back roller in the screw B, and as it travels 16 inches before it drops into the lower screw, the pins will comb the whole length of any staple under 13 inches long. The staples and locks are often so matted, that they would be broken if the fallers carried many pins, and as the work of the first box is straightening, rather than opening, many boxes have only a single row of pins set half-an-inch apart. As soon as the staple is free from the back roller it is naturally carried forward by the fallers at their own speed, until its tip reaches the nip

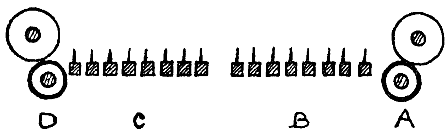


FIG. 37

of the front rollers C. These rollers are paying out 36 inches for every 6 inches moved by the fallers, and as soon as they get hold of any fibre, they pull it through the pins of the fallers at the same relative speed as the fallers moved through it, when it was held by the back roller.

From the front rollers the thin film of wool, $\frac{1}{36}$ the thickness of that which was fed up to the box, is carried forward by the sheet E until it touches the upper sheet F, and round this it is allowed to travel until a lap is formed which is thick enough to be fed up to the next box. As the drafts of the two boxes are equal, it is probable that the weights fed up will also be the same in both, and 36 revolutions round the leather will be required before the lap is thick enough to be fed to the second "sheeter."

The process in the second box is in all respects like

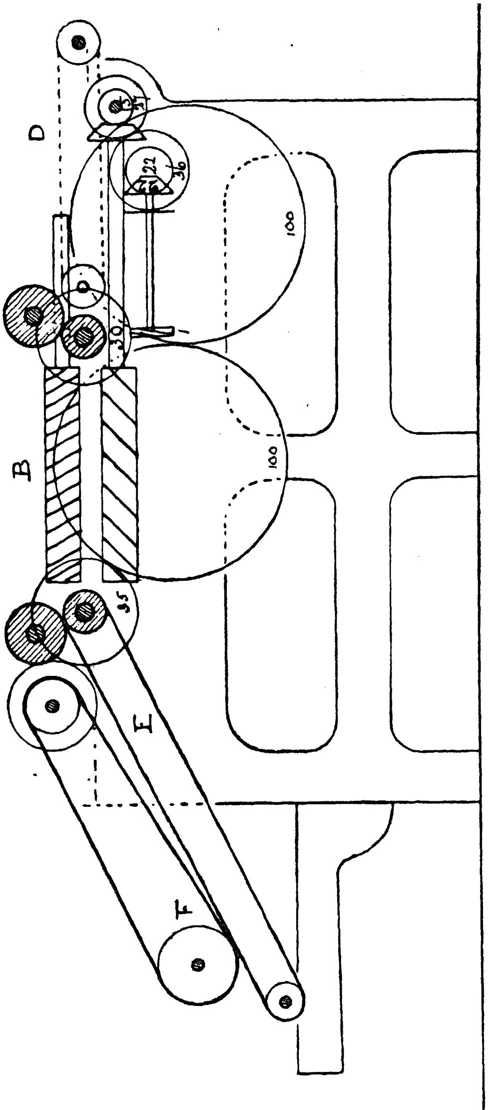


FIG. 38.—FIRST PREPARING-BOX OR SHEETER, WITH SCREW-GEARED BACK ROLLERS

the first; in fact, there will be no further need to refer to the action of the faller pins on the wool, because in all gill-boxes the combing and the drafting are on the same principle, the only difference being caused by the number of pins in the fallers and the relative speed at which they move. It would, in fact, be easy to find the relative value of work done at each gill-box by multiplying the inches the fallers move past the fibre by the number of pins per row and rows in any given distance, say, 1 inch. This must be done for each draft, and the two added together.

Fluted Rollers.—Before going into the question of calculations for drafts the output of fluted rollers must be carefully considered, because there is no method of calculation which will give accurate results when compared with the actual output of any fluted roller. As a matter of fact, this absence of any such formula by which the output can be calculated is not very serious in the practice of drafting of gill-boxes, because, where both back and front rollers are fluted, they are both affected in a similar way, though not to exactly the same extent.

Probably the first rollers used in gill-boxes were round and smooth, and it was early seen that such rollers had not sufficient grip on the wool. To increase this gripping power many devices were tried, the most effective being a system of fluting the rollers in such a way that the prominences of one roller fit into the hollows of the other (Figs. 39 and 40). Clearly, this system must give the roller great hold on the fibres; but it has one great drawback, for when the rollers are running fast under normal pressure, and only drawing a thin ribbon of wool, the friction of one flute against the next was soon found to cut the fibres. This cutting was overcome by running an endless leather apron

(always known in the trade as a "leather") between the two rollers. The substance of the leather prevents the two iron surfaces cutting the fibre, and it also acts as a cushion against which the flutes of the upper roller can grip the wool very firmly, and so increase the drawing power of the rollers. In all calculations it must be remembered that the presence of a leather affects the output, and that leathers are as a rule only used on front rollers.

To understand the whole question thoroughly it will be best to consider the action of a pair of smooth, round rollers. It is clear that such a pair of 3-inch rollers, running at 60 revolutions per minute, would pay out $\frac{3 \times 22 \times 60}{7} = 566$ inches per minute. If a leather were running between them it would be paid out at exactly the same speed, and if these rollers with the leather on them were drawing a sliver, they would deliver just 566 inches in the same time. With fluted rollers the output under each of these three conditions would be different, and, in addition, the output would alter if a very thick sliver took the place of a thin one.

The output of a fluted roller is often stated as $3\frac{1}{7}$ times the diameter of the mean line A (Fig. 39), which lies half way between the tips and the deepest part of the flutes. This estimation may be correct at times, but it is not at all reliable. It is not easy to see how the output can be less than a line drawn from point to point of all the flutes on the circumference of the roller. In the following calculations the output is reckoned as the diameter *over* the flutes $\times\ 3\frac{1}{7}$.

If a very thin tape were run through two bare steel-fluted rollers (Fig. 39) under heavy pressure the output per revolution would nearly equal the total length of the line B, representing the outside of the driving roller or 5 times the diameter of the mean line A. With a

thick leather, which could not be pressed so deep into the flutes, the length would come much nearer to $3\frac{1}{7}$ times the total diameter, and the output of sliver from such a pair of rollers with a leather on them would naturally be less than the output of the *same sliver* from the rollers working without a leather.

The draft calculations in preparing and other gill-boxes come very nearly accurate, because the sliver, coming through the back rollers, is many times the thickness of the sliver between the front rollers. The thick sliver keeps the back rollers apart, and affects their output very nearly to the same extent as the leather and sliver together affect the front rollers.

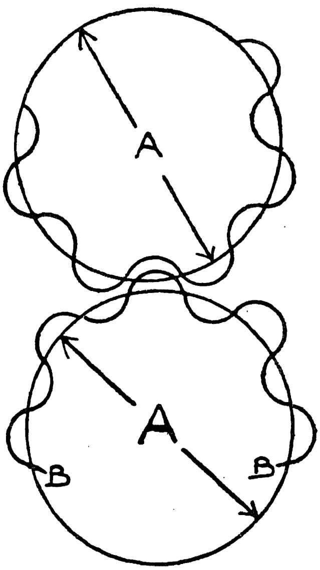


FIG. 39.

These statements are not easy to prove by writing and diagrams, but they are very easy to demonstrate in practice. It was the alteration of a gill-box with smooth back rollers and fluted front rollers that drew attention to the difference between actual and calculated output. If the rollers of such a box be run, without the fallers, and a tape be run through each pair of rollers in turn, first with the leather on, then without it, and finally with the tape on the top of a thick sliver (with the necessary weight taken off the pressing screws), it will be easy to see the impossibility of getting the same results in theory and practice. To do so it would be necessary to know the exact thickness of the sliver and leather taken together, when

under pressure, and even then the calculation would not be easy.

In Fig. 40 the front rollers of a gill-box, and the method of applying pressure to them, are shown, apart from other portions of the machine. The low roller revolves in long bearings firmly fixed to the framework, and pressure is applied to the upper roller through the long bushes E, the springs D, and the wheels B, which in this case press against the hinged lever A in such a

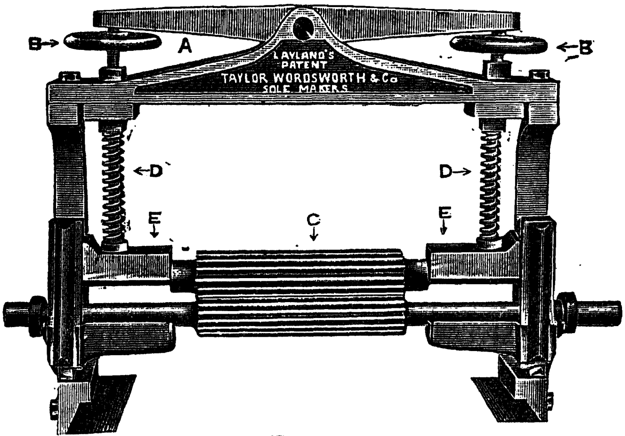


FIG. 40.

way that the weight is always equal on both ends of the roller.

In all gilling processes which are included under "combing" it is customary for the leather to run over the lower front-fluted roller, and downwards round a wooden carrying roller. In drawing boxes, on the other hand, the leather is usually on the upper roller with the carrying roller up above. In the first type the fallers*

* Fallers are now almost always made of solid steel, with the pins driven into holes which are bored right through them. The familiar name of "gill-box" has therefore become a misnomer, because it is derived from the early name for fallers which were called "gills" when they themselves were not bored to take the pins, but had the pins set in brass strips which were soldered on to the faller.

are more visible and easier to get at, but, as the leather has to run between the fallers and the low roller, it is not possible to get the pins of the fallers quite so near to the nip of the rollers as in the case of rollers with an upward leather. For the reasons given on page 127 the second type would therefore have its advantages for all sorts of wool which contain much short fibre.

TABLE IX

Draft for Third Preparing-Box (Fig. 41)

$3\frac{1}{2}$ inches front and back low rollers, equal to 11 inches circumference. Screws $1\frac{1}{8}$ inch pitch, single thread.

$$\text{Front draft, } \frac{\overset{\text{Front Roller.}}{11}\times 15\times \overset{\text{Bevel Wheels.}}{22}}{35\times 22\times \underset{\text{Screw.}}{1\frac{1}{8}}} \quad - \quad =\frac{88}{21} \quad =4\tfrac{4}{21}$$

$$\text{Back draft, } \quad - \quad \frac{\overset{\text{Screw.}}{1\frac{1}{8}}\times 22\times 75\times 80\times 75}{22\times 18\times 25\times 25\times \underset{\text{Back Roller.}}{11}}=\frac{90}{22} \quad =4\tfrac{2}{22}$$

$$\text{Total draft, } \frac{11\times 15\times 22}{35\times 22\times 1\frac{1}{8}}\times\frac{1\frac{1}{8}\times 22\times 75\times 80\times 75}{22\times 18\times 25\times 25\times 11}=\frac{88}{21}\times\frac{90}{22}=17\tfrac{1}{7}$$

The figures for the same box, with screw gear to the back roller (Fig. 38) would be

$$\text{Total draft, } \frac{11\times 15\times 22}{35\times 22\times 1\frac{1}{8}}\times\frac{1\frac{1}{8}\times 22\times 36\times 30}{22\times 27\times 1\times 11}=\frac{88}{21}\times\frac{90}{22}=17\tfrac{1}{7}$$

For boxes with smaller back drafts a double-stud gear (Fig. 42) is used in place of the treble-stud or screw gear, and for a fifth preparing-box geared in this way, with 3-inch rollers of, say, 10 inches circumference and 1-inch pitch screws, the figures would be—

$$\text{Front draft, } \frac{\overset{\text{Circumference of Front Roller.}}{10}\times 15\times \overset{\text{Bevel Wheels.}}{22}}{35\times 22\times \underset{\text{Pitch of Screw.}}{1}} \quad - \quad =\frac{30}{7} \quad =4\tfrac{2}{7}$$

$$\text{Back draft, } \quad - \quad \frac{\overset{\text{Pitch of Screw.}}{1}\times 22\times \overbrace{75\times 72}^{\text{Double Stud Gear.}}}{22\times 16\times 15\times \underset{\text{Circumference of Back Roller.}}{10}}=\frac{9}{4} \quad =2\tfrac{1}{4}$$

$$\text{Total draft, } \frac{10\times 15\times 22}{35\times 22\times 1}\times\frac{1\times 22\times 75\times 72}{22\times 16\times 15\times 10}=\frac{30}{7}\times\frac{9}{4}=9\tfrac{18}{28}$$

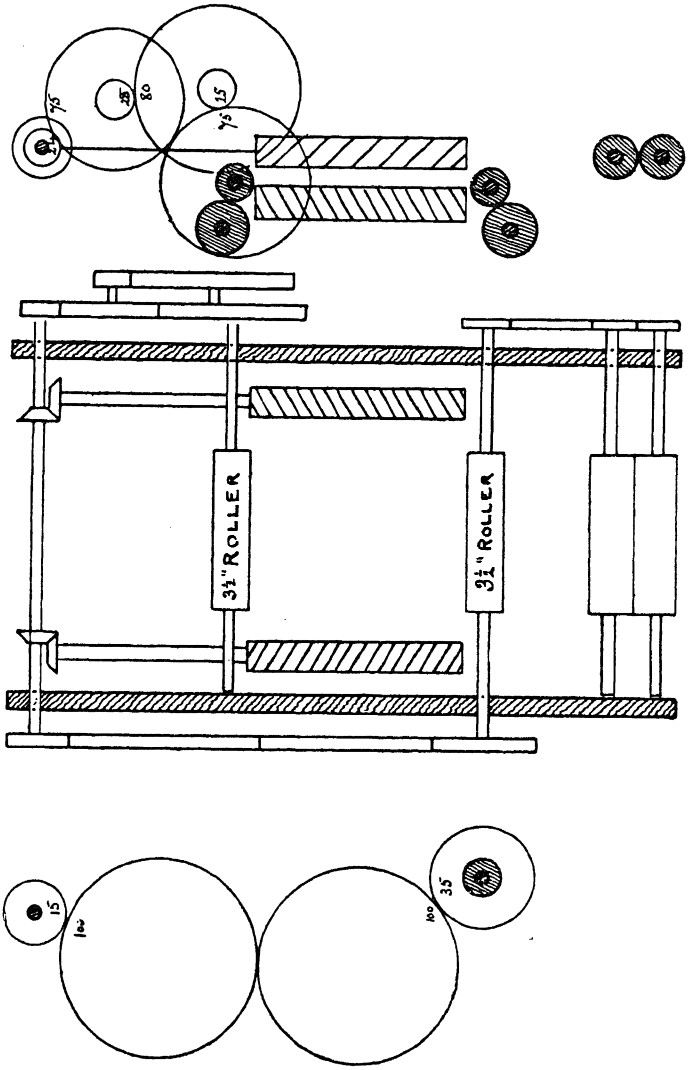


FIG. 41.—PLAN AND SIDE ELEVATIONS OF SECOND PREPARING-BOX WITH 3-STUD GEAR TO BACK ROLLERS.

The figures for all the succeeding processes are so similar, that it is not worth while to give more of them here, as almost all boxes are built on the lines of the

double-stud can box, given above, only varying in the size of their rollers and the pitch of their screws and gearing. If the correct output of each roller and the number of fallers per inch be inserted in place of the

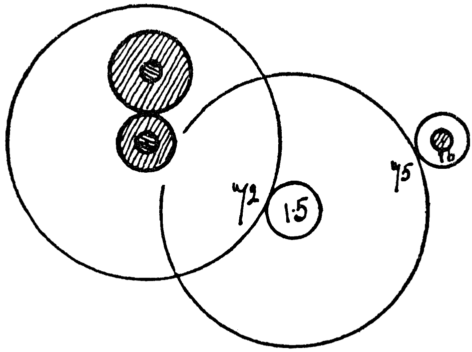


FIG. 42.—DOUBLE STUD GEARING.

figures 10 and 1, it is a very easy matter to alter the wheels to give any desired draft.

With the drafts given on Table VII., page 106, a set of preparing-boxes would do about 1,000 lbs. per day of good 40 half-bred hogs, and the weights of sliver and number of slivers put up at each box would be as under—

TABLE X

OUTPUT OF PREPARING-BOXES

	Ounces of Wool put up per Yard of Feed-Sheet.	Number of Ends up.	Ounces per 10 Yards.	Total Draft.	Ounces in 10 Yards of Resulting Lap of Sliver.
1st Sheeter . .	56	—	—	36	15½
2nd ,, . .	56	—	—	36	15½
3rd Can Box .	48	—	—	16	30
4th ,, . .	—	9	30	12	22½
5th ,, . .	—	8	22½	10	18
6th Backwash .	—	8	18	9	16

CHAPTER VI

INTERMEDIATE PROCESSES

Backwashing.—The principles of this machine are so simple that little need be said in explanation of the washing and drying apparatus which compose it.

The process is, of course, primarily intended to improve the colour of the carded sliver so that the top may be as white as possible. For this purpose there are two small bowls, each with a single pair of squeeze rollers to press out the sud from the wool after immersion. The low roller C is of brass, the upper roller is of iron covered with tightly wrapped wool.

As wool comes from the card it contains sufficient dust to affect its colour perceptibly, especially for some time after the carding-machine has been ground. The oil applied after washing makes this dust adhere to the fibre, and hence it is necessary to wash out all the oil, although a further quantity has to be put on in its place before the wool goes through the first gilling process. The amount of dirt in the carding is usually so small that only the best soap is used with the water in the bowls. The wool is always treated in sliver form, so there can be no agitation by forks or other means, and squeezing is therefore the only method of getting out the dirt.

The feed-rollers A (Fig. 43) have exactly the same surface velocity as the squeeze rollers—they draw the slivers from the cans, and in the simplest type of machine the wool goes at once under a single submerged

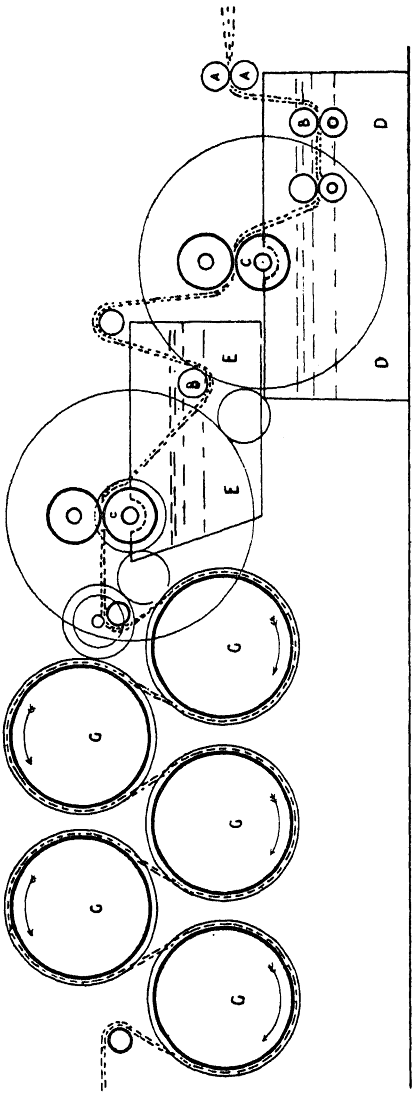


FIG. 43.—SECTION OF BACKWASHING MACHINE.

A. Feed rollers; B (in bowl D), submerging and squeezing rollers; B (in bowl E), simple submerging roller; C C, squeezing rollers; D, low bowl; E, upper bowl; G G, hot cylinders.

brass roller B (as in the upper bowl E). No dirt is taken out until the wool reaches the large squeezing rollers C, but in cases where the carding had been stored in ball, or was unusually dirty for other reasons, this one squeeze was considered insufficient. To increase the washing power some bowls are made with one or two pairs of small brass submerged squeezing rollers B, arranged as in the low bowl D, in place of the one immerser. As the wool could not pull these rollers round, the shaft of the low roller is carried through a gland in the side of the bowl and is driven by a chain, pressure being applied to the upper roller by the simplest possible method of dead weighting. It was shown in Chapter II. that all wool fibres tend to separate when under water; the sliver therefore becomes very bulky when immersed, and it holds enough water when lifted from the sud, to increase the strain very much and decrease the tensile strength of the sliver at the same time. Those who have used the immersed squeezing rollers say that they not only give extra washing power, but, being positively driven, they take some strain from the sliver, and by preventing it floating too loosely in the sud, they actually increase its tensile strength.

The same object may be attained by the use of the immersing roller and a three-roller squeeze head, on the same principle as that mentioned in the chapter on washing. The nip of the rollers (A and B) (Fig. 4, p. 33) being submerged, the wet sliver is never lifted from the sud. There is no need to prevent the fibres spreading, and as they float into the nip as far apart as possible, it is very easy for dirt to escape.

Both first and second bowls are made alike in all respects, but the second bowl is usually at a higher level than the first, to allow sud to run down without the help of an injector.

The marked affinity which soap has for wool is very obvious in this process. The sud in the bottom bowl should be strong enough to do the washing, and the upper bowl should have no more soap than will prevent the rollers cutting. If wool were kept running through two bowls so made up, it would soon be found that the lower one lost much of its soap, and that a great proportion was transferred to the upper bowl. The low squeeze rollers succeed in pressing almost all the water out of the sliver which passes through them, but when the sud is strong an appreciable amount of soap is left adhering to the fibre, as it goes to the upper bowl. So long as the water in the upper bowl contains but little soap, it continues to dissolve this soap from the fibre, but as it gradually increases in strength it absorbs less and less soap from the fibre, and the sliver consequently carries more and more soap with it through the final squeeze rollers.

All soap which gets through the upper rollers goes forward to be dried on to the fibre in passing over the hot cylinders; and in extreme cases this soap will affect the handle of the top, by tending to saponify some of the oil applied at the gill-box.

The simplest way to keep the suds uniformly strong is to run hot water continuously but very slowly into the upper bowl at such a speed that the soap strength and temperature will remain constant. By means of an overflow the excess sud will run down to the first bowl, and the addition of a very small quantity of soap to it, from time to time, will suffice to keep both bowls at the desired strength.

In cases where the natural colour of the wool is not good enough, it is now very general to use artificial colour to improve it. All kinds of colouring agents are used, but probably aniline violet is the commonest,

with aniline blue for special cases. Different qualities and shades of top take the dye very differently, and if it is desired to get tops of the same tint from two lots which differ in their natural colour, the only safe plan is to experiment in the bowl with one or two pound samples, and have one of them passed by the maker before proceeding with the bulk. This need cause no irregularity or waste, for even if the samples were far wrong they could be blended in with the bulk before backwashing so that they would never affect the colour of the top.

Most aniline colours have so much affinity for wool that if sufficient were put into the bowl to tint 100 lbs. of wool a large part of it would at once be absorbed by the first few yards of sliver, which would be dyed far too dark; the dye would be exhausted, and the remainder of the lot would gradually get lighter and lighter.

When dye is used in sud, it has much less keen effect than when used in water alone, but, unfortunately, there are two reasons which make it difficult to use dye in water only. If the first bowl were used for dye and the second for sud a great deal of the dye (which is not fast) would be washed out in the second bowl. On the other hand, if the low bowl were used for sud and the second for dye, the soap, as already stated, would gradually travel up to the second bowl, and as the proportion of soap increased the colour on the sliver would decrease, and the first part of the lot would be darker than that which came through later. To obviate this, the colouring-matter must be dissolved to a known strength in a vessel with a tap, and the solution must be run drop by drop into the sud in the upper bowl, so that the depth of colour in the sud is always uniform.

Drying.—From the last squeeze head the sliver goes direct to the hot cylinders G to be dried. They are

arranged so that first the upper and then the under surface of the sliver is in contact with the heated iron. With a five-cylinder machine the sliver changes its position five times, both sides being fairly dried, but in a thick sliver the moisture cannot be evaporated evenly right through it, the outside being drier than the inner layers. Some machines have a fan which is arranged to drive the warm air through the sliver by enclosing the cylinders in a case, and so with less heat to make the drying more uniform. It is the reduction of heat rather than the uniform drying that is important, for the gill-box will blend the wet and dry fibres uniformly; but we have taken it as an axiom all through that excessive heat injures the wool and when the moist wool rests on the steam-heated iron, the water in the wool must be raised to a temperature far above 110° F., probably nearer 200°. Such treatment would tend to raise the scales on the wool, making it rougher or sharper to the touch, and doing something to spoil its spinning power.

Perry's arrangement for drying consisted of a large number of small steam-heated rollers arranged in the form of a horse-shoe to make them easily accessible; the relative position of the sliver was reversed at each succeeding roller, and by these numerous changes it was hoped to prevent any baking or undue rise of temperature. Doubtless this result was attained, but it is probable the amount of steam necessary to dry a given weight of sliver was greater than in an ordinary machine.

Oiling.—As the wool leaves the hot cylinders oil is again applied, the quantity being regulated to suit the nature and quality of each individual lot. (See Chapter XIII.)

So many different methods are adopted for putting

on the oil, that it is difficult to choose between them. The essential points in any oiling motion after back-washing are very similar to those which are essential for washing.

1. It must be easy to see, and regulate accurately, the amount of oil applied in a given time.

2. The supply must stop directly the machine is thrown off, or a pool of oil will form on the sliver.

3. It must start automatically with the machine.

The brush motion, already described in Chapter II., puts on the oil in the most finely divided condition, but it is difficult to confine the spray to the exact place where it is required, and a calculable quantity of oil is lost. Moreover, there is not the same necessity for fine division here as there is in the washing, because the sliver goes at once through the rollers and fallers of the gill-box; these effectively mix the oil with the wool, and during the time the balls lie stored, prior to combing, it is easy for the oil to permeate all the fibres.

Many people still use the simple roller revolving in an oil bath, with a number of scrapers or small conduits hinged, so that one end can rest on the surface of the roller and scrape off the oil. As the roller revolves the oil runs down these conduits and drops from their fine points on to the wool passing underneath. The amount applied can easily be regulated by the number of conduits which are allowed to rest on the roller, as well as by the speed at which the roller revolves. The total quantity used in a day can also be easily measured by the sight glass in the tank, but as the oil bath is not always at the same level there is always some uncertainty about the amount applied in a short period. Except in the case of very small lots, any slight temporary irregularity can have no permanent effect, for it is shown elsewhere that there are 64,800 doublings before the backwash sliver is converted into a top,

and after being averaged so thoroughly it is most unlikely that any irregularity can be visible.

Some more perfect method which would apply oil to small and large lots alike, with absolute regularity, would be at least a theoretical improvement, and a machine which claims to fulfil these conditions is now in use; but it is a cumbrous arrangement, and somewhat costly. There is a cast-metal oil tank A (Fig. 44), into which a large square plunger B is lowered by screw gearing, driven from the machine. The oil is displaced as the weight descends, and runs over a lip of the tank C direct on to the sliver passing underneath. If the oil were to remain level with the lip when the machine was standing it would continue to drip for a long time, and to prevent this happening there is a second plunger attached by a cord D to the starting lever, in such a way that, when the machine is running, the plunger rests on the bottom, but is raised several inches when the machine stops. The raising of the plunger naturally lowers the level of the oil sufficiently to prevent any dripping.

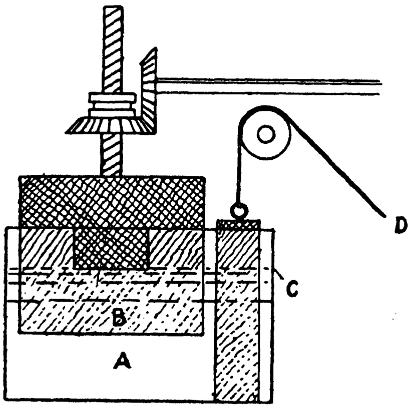


FIG. 44.

The Gilling Process, through which the dried sliver now goes, is exactly similar in theory to all those described under the head of preparing, and for long wool the sixth preparing-box would do equally well to follow the backwashing. There is, therefore, no need

to repeat details, but in carded qualities this is the first gilling process through which the wool goes, and the shortness and fineness of the fibres make smaller rollers and finer pins necessary to hold the wool. The particulars here given may be taken as typical of boxes suitable for Botany and medium crossbred, but different firms employ very different boxes and drafts for equivalent qualities.

	Back Rollers.		Flutes per Inch.	Pitch of Screw.	Fallers.		Front Rollers.		Drafts.		
	Bottom.	Top.			Rows of Pins.	Pins per Inch.	Bottom.	Top.	Back.	Front.	Total.
Crossbred .	3	3	5	$\frac{5}{8}$	2	14	3	3	$1\frac{1}{2}$	6	9
Botany .	$2\frac{1}{2}$	3	5	$\frac{1}{2}$	2	15	$2\frac{1}{2}$	3	$1\frac{1}{2}$	4	6

Both Botany and carded crossbred qualities are, of course, very much shorter than the long prepared qualities, and the drafts have to be reduced almost in proportion. There is a common saying that "the draft should be equal to the length of the wool," and if the length of the wool be stated in inches it is not very far wrong, but if centimetres were the standard of measurement the draft would have to be about $\frac{1}{3}$ of figure representing length.

In preparing, the big back drafts make this theory quite wrong, and even in Botany gilling it is not always correct, but it serves as a useful basis for experiment. For a Botany wool containing fibres 4 inches long, the draft would usually be about 5 in the earlier boxes, and of this total the back draft would only form a very small part, say, $1\frac{1}{4}$ or $1\frac{1}{8}$; and if the same box were used for an 8-inch crossbred requiring a draft of 9 it

would only need a slight alteration to make the back draft $1\frac{1}{2}$ and the front 6.

If a Botany sliver coming from this box be carefully opened and examined, it will be seen that there are rows of knots and short wool at regular intervals right across it. Every faller as it drops lets go the short fibres it holds. There is one faller in every half-inch, but as the sliver is drafted $4\frac{1}{2}$ after leaving the fallers, the marks appear in the sliver at regular intervals of $2\frac{1}{4}$ inches. In Chapter XIII. it is shown that wool, of which the longest fibres are 4 inches, will contain a great deal of fibre between 1 inch and half-an-inch in length, which will be made into noil at the comb. When the difference between the long and short fibres is greatest, the difficulty of making a perfect gilled sliver is greatest also.

An illustration will best explain the reason. The longer fibres, which extend through the pins of five or six fallers to the nip, continue to be drawn steadily all through the process, but with the very short fibres it is quite different. They are only held by one faller at once. In a box with $2\frac{1}{2}$-inch low roller carrying the leather, and a 3-inch top roller, when a $\frac{1}{2}$-inch pitch faller is at its nearest point to the rollers, the front row of pins will be about $\frac{7}{8}$-inch from the nip. (See Fig. 45.) The points of the shortest fibres do not extend even this short distance, and, therefore, none of them are drawn out *until the faller drops*. Then, as shown in Fig. 46, there is a gap of $1\frac{3}{8}$ inches between the nip and the first row of pins. All the fibres less than $1\frac{1}{4}$ inches which were held by the faller are now quite free; they are carried forward by the long fibres, and go through the rollers, and form a mark right across the sliver. This action takes place in the gilling of all uncombed wool. Where the proportion of short is very small (*i.e.* in the best wools) the resulting un-

evenness is nearly invisible, but where the proportion is larger, the sliver may be so lumpy that the proportion of top and noil is seriously affected. It is to minimise this evil that fallers are always made as narrow as possible for all stages of Botany gilling, and for the same reason screws and saddles are always set so close to the front roller that the fallers only just clear the front roller or the leather which works over it as they drop into the lower screw.

It is doubtful if this explanation will serve to make

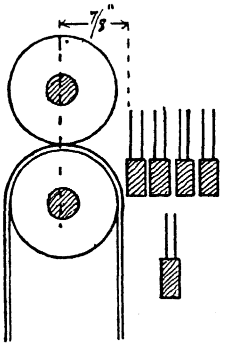


FIG. 45.

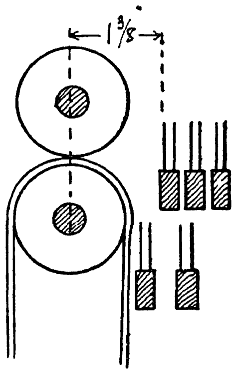


FIG. 46.

clear all that is embodied in the theory to those who are not users of gill-boxes; but if any student will experiment on the lines indicated, the suggestions offered will not be without value to him.

From the front rollers the sliver may go direct into a can, or it may be wound into good-sized balls on a balling head. (For details of balling head see end of Chapter XII.) Single-width machines making only one sliver or ball would have the rollers and leathers about 12 inches wide and the fallers pinned over $10\frac{1}{2}$ inches, double machines being about twice those dimensions and making two balls or two can slivers.

Preparing-Boxes.—Between the backwash box and the comb there are two more gill-boxes, which serve to open and straighten the wool still further before it goes into the circles. The value of these two boxes can be most easily judged by combing two similar lots—one prepared, and the other straight from the backwash gill-box. The lot which had been three times gilled would be slightly longer and would yield more top with less noil. If one box were used after the backwashing instead of two, the process would be worse than useless, and in the same way the use of three preparing-boxes would do more harm than good. This is because the direction of the sliver is reversed at each operation between the card and the comb, and to get the best result *the wool must go to the comb in the same direction in which it comes from the card.* After four reversals it is of course in its original position, and for this reason the four operations of backwashing, first preparing, second preparing, and the punch-box give the best results. If one or three preparing-boxes were used there would be an odd number of processes, and the direction of the sliver would be reversed.

If a carded sliver be drawn apart, the two broken ends will differ considerably—one is thin and pointed, the other is thick and squarer in appearance. The thick end has the bulk of its short fibre very near to its extremity, and the manner in which the doffer takes the wool from the swift is accountable for this arrangement. Why the doffer should arrange the fibres in this way is not quite clear. The fact must be taken as it stands, and must not be attributed in any way to the original position of the fibre or the staple, in the fleece. In a Noble comb the short wool or noil is taken off from the inner circle and the sliver *must* therefore go up short end first, so that when it lies across the pins of the two circles at their point of contact, the short

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wool will be dabbed by the brushes in (See Chapter X.)

Botany preparing-boxes are so much li wash gill-box in particulars and drafts, tha no need to describe them again. They differ in the speed. The speed of the backwash gill is usu restricted by the drying power of the hot cylinders, and there is, therefore, no need to make the gill-box run fast and drop many fallers a minute. For this reason long fallers which are wide enough to gill two 10-inch slivers can be used without undue risk of breakage. There is no restriction to the speed of a preparing-box except the strains involved in running; and as high speed means reduction in cost of production, and short fallers can be run much faster than long ones, with less breakage, the preparing-boxes are nearly always narrow, say, 10½ to 11 inches over the pins. The first box will always have a can head, the second has usually a balling head; but cans have their advantages here as in other places, and they would probably be as easy to deal with as balls at the punch-box.

Theoretically, the *Punch-box* is not a process—that is to say, the fibres in the sliver do not alter in any way in their relation to one another. The object of the machine is simply to make up the wool into balls, which will enable the greatest possible length of sliver to be put into the creel of the Noble comb. To do this four ends must be built up side by side into a tight ball, with no crossings whatever, so that when it is slowly unwound in the comb creel, each of the four slivers will run easily and straight into its own conductor. The essential points of a good punch-box are

1. That the ball is built without a bobbin.
2. That sufficient tension or pressure to build a firm ball can be applied to the ends without straining them.
3. That the ball can be easily and quickly "doffed" and the box quickly set and restarted.

CHAPTER VII

COMBING—HISTORICAL SUMMARY

As early as A.D. 1789, five years after the famous Dr. Cartwright had patented his first power-loom, he turned his attention to the construction of a machine to comb wool, for he tells us that at that time "there cannot be less than 300,000 packs of wool combed per annum at an average cost of £800,000 or £1,000,000," or an average of $2\frac{2}{3}$d. to $3\frac{1}{3}$d. per lb.

In the case of his power-loom the great inventor had only to unite and make automatic the various motions then existing in the handloom; but it was entirely different with regard to a machine to comb wool. He had to invent the entire mechanism; but such was his enthusiasm for the work that in the following year, 1790, he took out his first patent for a machine with rows of teeth or pins set in the edge of a cylinder in such a way that they might clear or comb out the wool held in the teeth of a fixed upright comb.

This system was greatly modified in subsequent machines, and, in referring to it a year or two later he naïvely says: "My system was brought to its present state of simplicity and perfection when I took out my third patent in 1792." In these days, we can hardly regard his machine as either simple or perfect, but he undoubtedly constructed machines which combed wool more cheaply and, probably, better than it could be done by hand, and had he not been badly treated, like almost all of the early inventors, he would probably have made a great commercial success of his original ideas.

As it was, his ideas were first derided, and afterwards stolen from him, and costly lawsuits instituted to maintain his rights only reduced him to such poverty that he was obliged to leave it to others to mature and perfect the idea of combing as he conceived it, and to reap the rich pecuniary reward which came in its train.

Cartwright seems to consider that his third machine was his best, and in it the principal comb consisted of a circular ring set with pins, which all pointed to the centre of that circle. On the other hand, his second machine had the pins set vertical, in a horizontal circle, on to which the wool was fed by a lashing motion. The circle was heated by a "stove pipe," and there was a contrivance to "stroke" the wool and a pair of vertical drawing-off rollers.

These five "novelties"—

1. The circle with vertical pins;
2. The heating of the circle;
3. The lashing motion;
4. The stroker;
5. The drawing-off rollers—

all exist in combs of the present day, some in one and some in another. The credit for all of them must be given to Cartwright, and he has especial claim to honour as being undoubtedly the first man to make and use what is now the root principle of nearly all wool-combing machines—a revolving horizontal circle set with vertical pins.

It was thirteen years after Dr. Cartwright took out his third patent that the name of James Noble appears on the register, claiming protection for an "invention to discharge a wool comb or combs by separating the tear from the noil and drawing what is commonly termed a sliver or slivers from the comb or combs after or before the combs were worked or the wool was worked upon the same." This patent appears to have

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come to nothing, and three others, taken out in 1833, 1835, and 1846, shared much the same fate. In 1853, almost fifty years after he filed his first specification, he met Mr Donnisthorpe at Leicester, and with his assistance a machine was evolved, and patented in the name of Noble only. It was on the principle of the modern "Noble" comb, but had only one inner or small circle. Both circles revolved in the same direction, with the same surface traverse, coming into contact at a point where the wool was introduced into the pins; and its simplicity and adaptability quickly secured its complete success.

Noble began work before any other of the men whose names are now borne by the well-known machines which they invented; but during the long interval between 1805 and 1853 many other inventors had been busy, and of the early combing-machines offered to the public, his was not the first which proved a complete success in practice.

In 1814 and 1827 a certain Mr Collier invented a machine which had more the appearance of a carding-engine than a comb, and although it was patented, and made by John Platt of Salford, it never came into general use; but thirteen years before the first Noble comb began work, three men, whose names are justly celebrated, and one who is much less known, were all at work separately, and well on the highway to success in their efforts to solve the same problem.

In 1841, all unknown to each other, Heilmann was working at Mulhausen in France whilst Donnisthorpe, Lister, and Holden were striving to overcome the same difficulty in Yorkshire.

Heilmann's nip comb was patented in England in 1846, and three years before that date Lister and Donnisthorpe had succeeded in combing fine wool on quite another principle at Manningham; and in the

latter part of that year they sold more than fifty machines to two Bradford firms. About 1849 they devised a nip motion and applied it to their comb, which made the work practically perfect; but as this arrangement infringed Heilmann's English patent they were obliged to buy up his rights, in order to remove their competitor from the field and to obtain the right to make the most perfect machine possible.

At the same time that Lister was working with Donnisthorpe to perfect the Lister comb, Holden was trying to construct a machine on a different principle. In 1847, with a view to their mutual advantage, Lister and Holden went into partnership, and in the next year in their joint names a combing firm was established at St Denis in France, which began work with Lister and Donnisthorpe combs. At the same time Holden and Lister were working together to perfect the Holden comb, and in 1848 the first patent in which the square motion is mentioned was taken out in the name of Lister only, although Holden always claimed to be the real inventor of the motion, and for many years a keen controversy was maintained as to the real origin of the patent.

The early square-motion combs made under this patent do not seem to have been sufficiently perfected to compete with the nip comb in practice; but Holden never ceased to believe that the principle was capable of perfect development, and after labouring for many years, taking out many patents, and fighting many lawsuits, he finally succeeded in evolving the machine which now bears his name. Machines were made and used continually after 1849, but it was not until 1856 that it came before the public as a comb which would do superior work, and since that date it has ranked second to none in the quality of the work it produces.

There is naturally a great desire both in France and in this country to receive credit for an invention of such importance as the first reliable machine to comb wool, and the only conclusion possible to an impartial mind is to award equal credit to both countries, for there can be no possible doubt that Heilmann in France and Lister and Donnisthorpe in Yorkshire each perfected combing-machines contemporary with, and in entire ignorance of, the work of the other, and nothing can show the thoroughness and ability of all these inventors better than does the fact that all the essential features of the machines they made are embodied in the respective combs which are known by their names to-day. Unfortunately, the name of Donnisthorpe is not associated with any particular type of machine, and there is keen controversy as to the share of credit due to him for the perfection of the Lister comb; but the names of Lister and Holden are still household words in the trade which their inventions helped so largely to bring to its present important position.

The whole subject is one of such great interest, and at the same time so intricate, that complete details would be quite out of place here, especially as full particulars can be readily obtained from Mr. Burnley's excellent and exhaustive work on "Wool and Wool Combing," which might with equal suitability have been styled "A Romance of the Worsted Industries."

As it would serve no useful purpose to go into the details of the many stages through which the various combs have been brought to perfection, it will be simplest to look first at the leading features and essential differences of the machines as they are now used, and after comparing the methods by which the wool is combed on each type of comb, to consider each machine in detail with a summary of its parts, its advantages, and disadvantages.

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In the *Lister or Nip Comb* the principal part of the clearing is done in the fallers A by means of the nip B, which draws a fringe of sliver clean away from each faller, pulling the fibres right through the pins before the faller drops, so that all that part of the fringe of fibre which is outside the actual jaws of the nip has

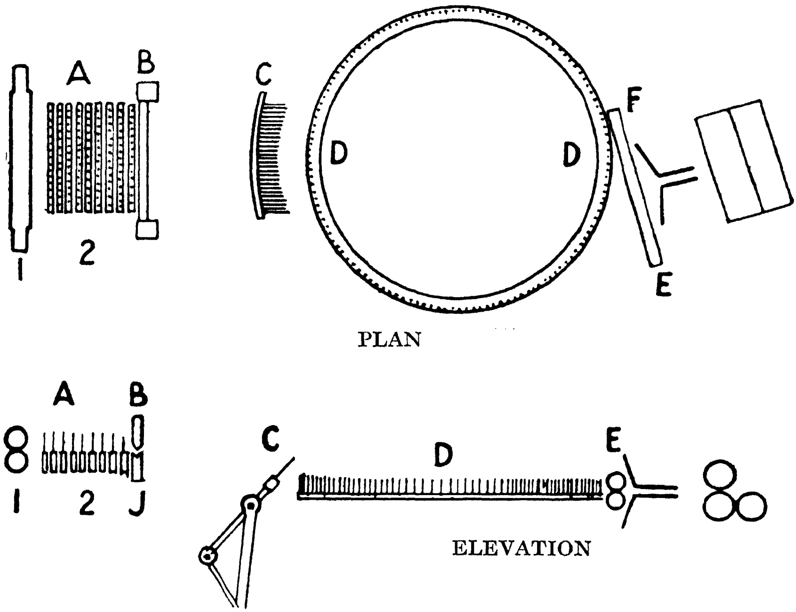

FIG. 47.—DIAGRAM OF LISTER OR NIP COMB

been combed clear. This tuft or fringe is arranged with all the short fibres at the nip end, so that when it is deposited on the circle D by the carrying comb C *the short wool and neps lie inside the pins of the circle with a long fringe of combed fibres outside.* As the circle moves round, these cleared straight fibres come round to the drawing-off rollers E and are drawn out of the circle pins to form the sliver, whilst the short wool and neps are left in and behind the pins and are removed

as noil. In theory this machine is very simple, but in practice very complicated mechanism is necessary to attain the desired result.

In the *Holden or Square Motion Comb* the wool is put on to the circle uncleared by the filling head, and the main portion of the staple or *fringe which hangs outside the pins of the large circle contains neps and short wool.* When this fringe reaches the square motion the pins of the fallers rise through it, and, moving away from the circle, comb out the short loose fibres and neps. (See Fig. 54, Chapter IX.)

After this clearing the fringe travels forward to the drawing-off rollers, and the long wool and noil are removed much as in the Lister machine.

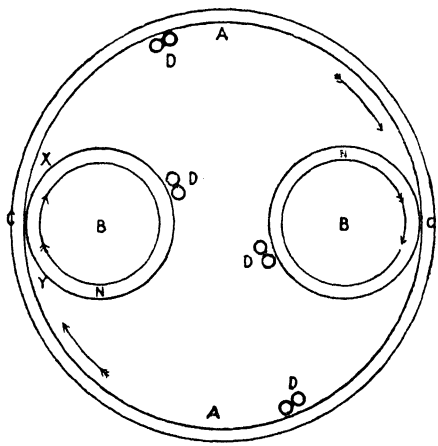

FIG. 48.—DIAGRAM OF NOBLE COMB.

In the *Noble Comb* the wool is simply dabbed on to two circles A and B at their point of contact D, and by their separation as they rotate a *fringe of long cleared fibres is left hanging from each circle with the short wool and neps within the pins of both circles.* The long fibres

are drawn through the pins by vertical drawing-off rollers D, and the noils are lifted out of the small circles at N N_1.

Heilmann's Comb as it is now made is the smallest machine of the four, and is principally used for cotton and very short wools.

The combing of short wool is not so common in this country as it is on the Continent, and for that reason the Heilmann comb is less used in England than the three machines already mentioned, which were invented in this country for the combing of longer wools. It differs from all other combing machines in having no circle of vertical pins into which the wool is pressed. Half the combing is done by the pins of a cylinder or porcupine, which are set point first, very much like the clothing of a card swift. As they rotate, the successive rows of pins comb a fringe of fibres which protrudes from the nip of the machine. They comb out all the neps and fibres that are not held by the nip, thereby covering the revolving cylinder with noil, which is removed by a revolving brush.

When the front end of the tuft is clear, an intersecting comb descends right through the tuft, in front of the nip, which rises to meet the drawing-off rollers. These catch the properly combed ends of the fibres and draw them out of the pin bed and through the intersecting comb in such a way that the whole staple, however short, is completely combed from end to end. The front is done first by the porcupine, the back end last, after the nip has opened.

CHAPTER VIII

LISTER OR NIP COMB

We have already seen in the historical summary that this machine must undoubtedly have the credit of giving the first great impulse to machine wool combing as an industry in Yorkshire, and it cannot be better described than it was many years ago, when first invented, by saying that "its method of putting wool on to the large circle was the nearest possible approach to the movement of the human hand and arm when doing the same work."

The machine consists of five important parts—the feeding head A; the nip B; the carrying comb C; the circle D; and the drawing-off rollers E. (See Figs. 47, 49, and 50.)

To allow of the drawing-off rollers being shown in section in Fig. 47, they are shown on the opposite side of the comb from, and parallel with, the fallers, although nearly all combs are made as in Fig. 49, with the drawing-off rollers at right angles to the fallers.

The feed head A is constructed on much the same principle as an ordinary gill-box, into which it is essential that the wool be fed short end first. As soon as the slivers have passed through the feed-rollers (A_1) they are pressed down into the pins of the fallers (A_2) by a barrel-shaped roller. The fallers are usually twenty-nine in number, of which nine are down and nineteen are up. They are always heated by gas or steam, with three rows of pins, and set over 16 inches.

When the comb was first introduced the fallers and

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nip were straight, but it was obviously impossible for a straight nip and straight carrying comb to put the full width of sliver uniformly on to the circular comb; and the fact that the wool from the centre of the fallers was put farther over the pins than that from the sides of the fallers necessarily made a very irregular tear, and a consequently heavy noil; and backing-rollers had to be arranged inside the comb to pull out the long hairs before the noil could be taken off.

Various devices were tried to remedy this serious defect; amongst them being a flexible carrying comb, which was straight when it took the wool from the nip but which bent into a curve resembling the curve of the circle before it delivered the wool on to the comb. This was a slight improvement; but it was not until the Busfield or curved fallers, A_2, Fig. 50 (which are lower in the middle than at the ends), were introduced, together with a curved nip J_1 and J_2, and carrying comb, that the Lister machine came into general use.

The Nip.—The place which would be occupied in a gill-box by the front rollers is taken in the Lister comb by the nip (B, Fig. 49 and Fig. 50), from which it takes its second name. This nip consists of a swing frame with two jaws. The whole mechanism is so constructed that it can swing to and fro from the first position B, where the jaws of the nip are almost in contact with the first faller just before it drops, to the second position B_1, shown in dotted lines in Fig. 49, where the carrying comb meets it. Whilst the nip frame is in motion the jaws are controlled by a cam G, so that the nip is open whilst it moves forward towards the wool which projects from the first faller, and upon this wool it then closes tightly, the rounded convex edge of the upper jaw J_1 fitting into the concave edge of the lower one J_2, so that the wool is held absolutely fast,

until the nip has again moved forward and met the carrying comb with the tuft, which has been

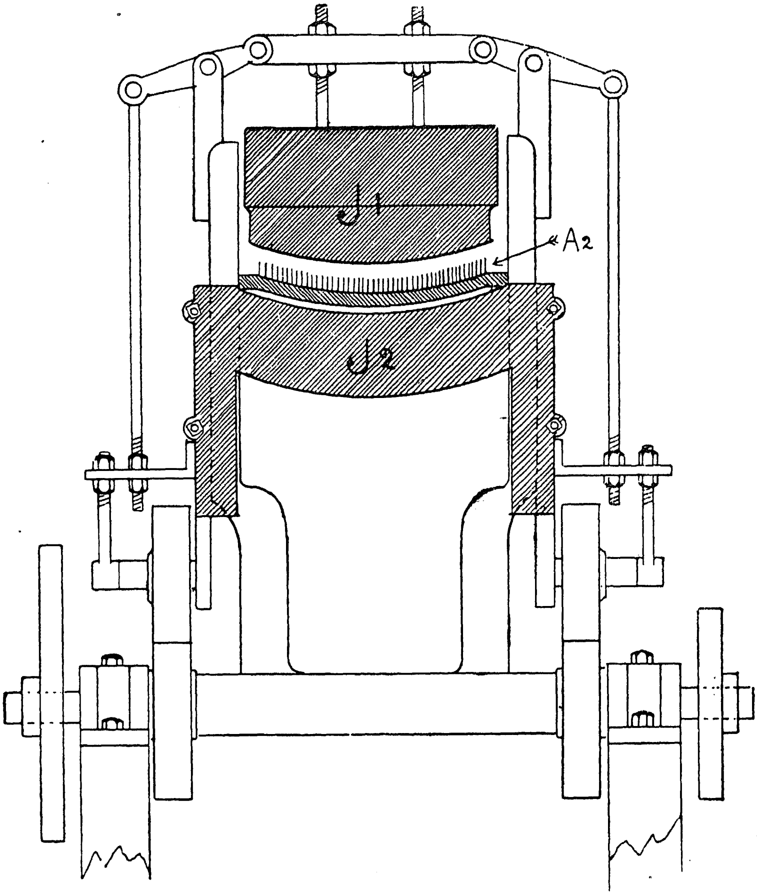

FIG. 50.—NIP OF LISTER COMB SHOWING JAWS J_1 AND J_2 AND CURVED FALLERS A_2.

The springs which give slight elasticity to the nip are not shown.

drawn right through, and away from the pins of the fallers.

It is to this quick forward motion of the nip that

the principal combing action of the machine is due, for it is obvious that as the long fibres are drawn through the pins of the fallers (A_2), they must leave behind them any short wool or neps which might be clinging to them, but which did not project far enough from the pins to be gripped by the nip.

It has already been stated that the wool should be fed into the fallers short end first, so that when the nip gets hold of a portion of sliver, it grips not only the long fibres, but also the short ones, for they are all arranged in a way which may be illustrated by Fig. 51, with the points of both long and short fibres projecting approximately the same distance beyond the pins of the first faller. The tendency of the fibres in the gills to arrange themselves in this way becomes more and more marked as the process continues, and this is just what is desired; for when the carrying comb places on the large circle a tuft made up in this way, it follows that all the noil is thrown within the outer row of pins, if not within all the five rows, and all the fringe of long fibres outside the circle pins is straight and free from neps, because it has been drawn right through the pins of the fallers.

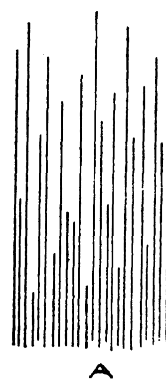

FIG. 51.

The mounting of the *carrying comb* C is very complicated, its movements resembling those of the human elbow and wrist very closely, as it travels in an elliptical course from the farthest point reached by the nip, to the circle. In shape it resembles one of the fallers, being crescent, with its two rows of slender pins 4 inches long (15 per inch), in the same plane as the circle of which the crescent is an arc, and quite parallel with

the nip, when the pins touch the jaws. As soon as the points of the carrying comb touch the nip, the whole comb rises and the pins run through the fringe of short fibres which project behind the jaws, which immediately afterwards open, so that the wool is released.

The carrying comb now moves forward, bearing on the points of its pins the fringe or tuft of wool it has taken from the nip, and when it reaches the circle D its peculiar motion has turned it partly over, so that its crescent shape allows it to be in equal contact with the circle along its whole length. The wool is now dabbed down into the comb circle by the brush H; the long thin pins are drawn away, and go to take another load.

In some machines there are two complete filling heads, set at right angles to one another, both complete with fallers, nips, and carrying combs, and both feeding on to one circle.

TABLE XI.—Particulars of a Lister Comb for 32s to 40s Quality (Fig. 49, facing page 144)

A_1.—Backrollers, 3 ins. diameter fluted (say 11 ins. circumference).

A_2.—Fallers, $\frac{5}{8}$ in. pitch, 19 up, 3 rows of pins 18, 16, and 12 per in., set over 16 ins.

B.—Curved Nip, 18 ins. wide.

C.—Curved Carrying Comb, 18 ins. wide, pins 4 ins. long, 15 per in.

D.—Comb Circle, 48 ins. diameter, 5 rows pins, set over $\frac{5}{8}$ in., with one or two rows of pins extra long ($2\frac{1}{2}$ ins.) to receive the wool from the carrying comb.

	1st row.	2nd row.	3rd row.	4th row.	5th row.
Pins per in.	20	19	15	15	14

E.—Drawing-off Rollers, horizontal, 2 ins. diameter, say $6\frac{2}{7}$ ins. circumference.

Gearing as shown in Fig. 49.

The rack is within the pins of the circle; this complicates the drive and makes necessary the 2 upright shafts and the upper stud wheel.

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TABLE XII.—Calculations of Speeds for a Lister Comb (Fig. 49)

With 190 revolutions per minute of the driving pulleys, the speeds will be

$$\frac{190 \times 28 \times 15 \times 20 \times 20 \times 17}{60 \times 20 \times 38 \times 35 \times 347} = \frac{1020}{1041} \text{ or } \left\{ \begin{array}{l} \text{1 rev. per min. of} \\ \text{large circle.} \end{array} \right.$$

$$\therefore \frac{1020}{1041} \times 48'' \times 3\tfrac{1}{7} = 148'' \text{ traverse of circle per min.}$$

The fallers, nip, and carrying comb are all geared together by equal sized wheels, so that they always move in exact unison, but they are only connected by a strap with the circle gearing because it is not important that there should be strict accuracy in the relation of the movements of the carrying comb and the circle.

To find the speed of the fallers—

$$\frac{190 \times 28 \times 14 \times 22}{60 \times 10 \times 72} = \frac{10241}{270} = 38 \left\{ \begin{array}{l} \text{fallers per min. and} \\ \text{swings of nip per min.} \end{array} \right.$$

And 38 fallers each $\frac{5}{8}$ in. pitch $=24$ ins. per minute. The back rollers make

$$\frac{10241 \times 20 \times 13}{270 \times 60 \quad 80} \times 11'' \text{ circumference} = 22\tfrac{6}{10}'' \text{ per min.}$$

So that there is virtually no draft between the back rollers and the fallers.

The output of the front rollers is

$$\frac{190 \times 28}{60} \times 6\tfrac{2}{7}'' \text{ circumference or } 557'' \text{ per minute.}$$

Or a total draft on the comb of $\dfrac{557}{22\frac{6}{10}}$ or $24\frac{7}{11}$.

This shows that the rack only makes 1 revolution per minute, giving a traverse of 148 inches per minute to the pins of the circle; but in one minute the nip will deliver thirty-eight fringes, each 16 inches broad, on to the pins, and these fringes or tufts will therefore over-

lap one another by 12 inches, so that when fully charged they will lie in the circle four deep arranged as in Fig. 52. By this arrangement the machine attains additional blending power, and at the same time the sliver will be much more uniform than it would be if only one layer were deposited on to each 16-inch section of the circle; but as the pins are filled nearly to their points, continual dabbing with the brush is necessary to prevent the wool rising and slipping over the pin points when it is drawn off by the rollers.

Drawing-off Rollers.—As the circle moves forward the long fringe of cleaned fibres hangs down in a position which is too low to be caught by the drawing-off rollers, so just before it comes to them it is stroked upward and slightly forward by an air jet or a mechanical stroker, which directs the points of the wool straight into the nip of the rollers.

FIG. 52.

The method in which the wool is drawn off is peculiar and worthy of special attention, for the long and short fibres which now form the fringe all have their roots equally deep in the pins of the circle; and as they come round to the horizontal drawing-off rollers (E, Fig. 47) (which are set at a tangent to the circle), it stands to reason that the tips of the longest fibres only will first touch the rollers and be drawn off by them at or near the point E (Fig. 47). When the long fibres are gone and the circle has moved a few inches farther, the medium fibres will be drawn near the centre of the rollers, where they will first come within reach of the nip, and the very short ones, which may only project half-an-inch from the pins, will not be caught until they have travelled to the far end of the roller, where it all but touches the circle at F.

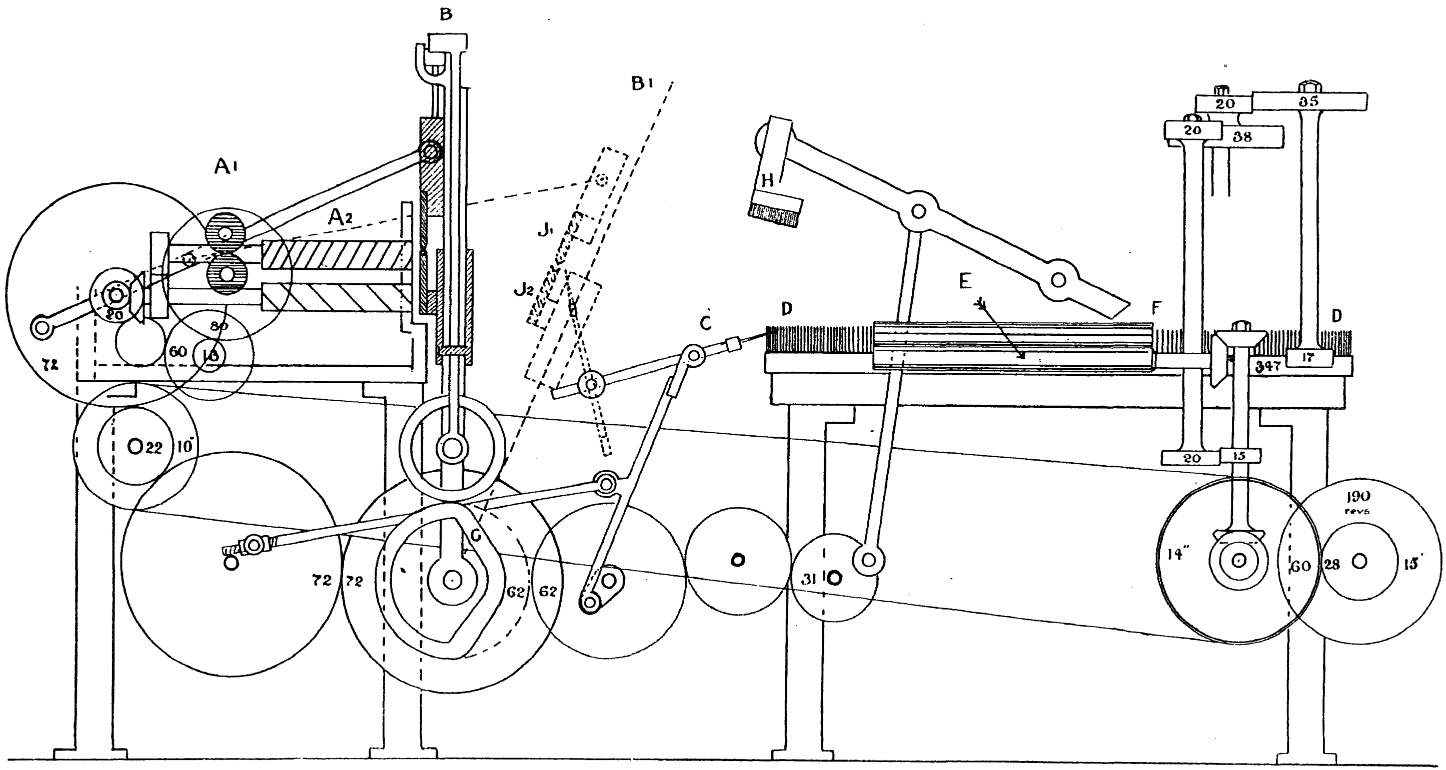

FIG. 49.—DIAGRAM OF LISTER COMB, MADE BY MESSRS. HOYLE AND PRESTON
Where two Bevel Wheels are of equal size, no figures are given or shown in the calculations

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This makes a type of sliver known as the *hen-wing*, which is peculiar to all combing-machines with *horizontal* drawing-off rollers. All the long fibres lie on and travel up one side of the drawing-off leather, with all the short ones on the other side; so that when the sliver is rolled in a revolving funnel, all the short fibres will be on the inside or outside, as the case may be, and not blended uniformly throughout the sliver, as in a Noble comb.

The noil is removed from the circle in a very simple manner by steel noil knives running between the rows of pins, which lift the short wool clear of the points of the pins, and place it within reach of the noil rollers or allow it to fall direct into a can provided for the purpose. The circle is now empty, and, after travelling another quarter revolution, is ready to be again filled by the carrying comb.

It must be obvious to the most casual observer that if these various processes are to be carried out properly great care must be exercised in timing and setting the different parts of the machine. The nip must close just at the instant the faller is at the front, and must move fast enough to complete the draw before the faller begins to drop, or the tail end of the staple will be freed from the pins, slipping over instead of being drawn through them, and bringing with it some of the short wool which ought to be left behind.

The carrying comb must just meet and slightly press against the nip, before the jaws open, or the tuft would fall. The dabber must be so accurately timed that it will press the wool into the circle just as the carrier comb is leaving it. It is necessary that the pressing barrel should be adjusted so as to press the wool firmly over the whole length of the fallers; and unless the jaws of the nip are an exact fit, they will either cut

the wool in places or leave uncombed tufts, when taking the wool from the fallers.

The cutting-off knife is another item which needs most accurate adjustment. It is set between the drawing-off rollers and the circle at the end where the rollers are nearest to the circle, to ensure that no straggling fibres are drawn after they have passed the end of the leather. If the knife be set too far forward there will be an unnecessarily heavy noil and consequent loss of tear; whilst, if it be set too far back, there is danger of slubby or twitty edges in the sliver, which is one of the worst defects that a top can have.

Taken as a whole, the machine of to-day differs very little in its essential parts from the type when first invented, although it is natural that a good many modifications have been made which are decided improvements. Unfortunately, there is one weak point which is very difficult to remedy; for if the carding be so rough and neppy that the fallers fail to clean it thoroughly the neps would be found in the fringe, so far outside the pins of the circle that no amount of extra noiling would remove them, and the only possible remedy is to comb the lot over again. Recombing is, of course, expensive, not only by reason of the extra wages paid, but also on account of the great proportion of noil made in the two operations.

The hen-wing sliver from the horizontal drawing-off rollers also has its disadvantages, for if a sliver contain a large proportion of short wool it is almost certain to be feather-edged or ragged on the short wool side, and it is exceedingly difficult to run such a sliver through a gill-box so as to make a perfect top. Ambler's method (under Patent 19532, Oct. 1894) of drawing the sliver on one slide of the table leather instead of straight across is, perhaps, the best way out of the difficulty;

but it does not alter the type of sliver, and for this reason, and still more from its inability to get a good tear from short fine wools, the Lister can never rank on an equality with a Noble comb, except for qualities of great and uniform length which are straight and not too full of noil knots.

If the machine has its weak points, no one can deny that it has its good ones, for when once set properly for suitable material, it will do good work and plenty of it, needing only a reasonable amount of attention. It costs little in repairs or in renewals of circles, fallers, leathers, and brushes. For short wools it has been supplanted by Noble's, but it still holds its own for long wools, and especially for mohairs and camel hairs, where heavy noiling ceases to be a disadvantage, and is sometimes positively desirable.

CHAPTER IX

THE HOLDEN COMB

THE Holden comb was introduced, as we have seen, shortly after the Lister had been adopted as a practical machine for the combing of long wool. It was designed primarily to deal with merino qualities, and as the two combs have several features in common it will be well to consider them both, before dealing with the Noble comb, which works on very different lines.

The principal working parts of the Holden comb are—A, the filling head; B, the circle; C, the square motion; D, the segments; E, the drawing-off rollers; F, the noil knives; G, the noil motions; and as each of these parts requires its own adjustment and a more or less complicated driving arrangement, the action of the machine will be most easily understood by considering the action of the various motions in relation to one another, and then analysing each part, with its driving and setting, as a separate machine.

The Filling Head.—The motion and action of the filling head A (see Fig. 53) is quite different from anything else in the trade. The first pair of rollers 3A, revolving continuously in fixed bearings, lift the slivers steadily from the balls or cans of carding behind the machine and hand them forward to the two filling heads A$2\frac{1}{4}$, $2\frac{1}{4}$, the rollers of which are not only continually paying out wool on to the circle, but are also working to and fro in an orbit (one coming forward as the other retires); so that the wool which extends

beyond the rollers of each head is lashed down at every stroke on to the pins of the circle B, and as each head draws back from the circle it leaves a fringe, or portion of its sliver, fixed in the pins of the comb. By this method of filling the wool is placed on the circle uncombed, with noil and neps existing in the fringe outside the pins. In the Lister, on the other hand, the great proportion of the combing is done in the filling head or gill-box, which has the great advantage that when it is once properly set it seldom needs to be altered; whereas this part of the Holden comb must be set with the greatest care when the machine is started, and must also be regulated to suit the average length of staple, of every lot that is put into the machine.

A reference to the chapter on tops will show the principles for ascertaining the average length of fibre in any sliver, which, for good Botanies, may be taken as about $2\frac{3}{4}$ inches, and as a rule, it may be taken that when the heads are at the point in their orbit which is nearest to the circle, the distance from the centre of their rollers to the outer row of pins should be just equal to the average length of the wool which is being combed. As each head comes to this point the barrel shaft should be on its dead centre, so that the motion of the head will carry the wool as nearly as possible vertically downwards on to the pins.

The barrel shaft has both vertical and horizontal adjustments, and to bring the rollers the right distance from the pins on the comb, after the head has been once properly adjusted, the barrel shaft should be lowered about half-an-inch for every inch which the filling-head rollers are taken back from the pins. With the heads set in this way it stands to reason that there must always be a fringe of sliver projecting beyond the rollers, and to prevent the fibres waving about, when the head is in such violent motion, the fringe is

supported on the under side by a row of short bristles, and on the upper side there is also a row of longer bristles, which both steady the wool and help to press it down into the pins of the circle.

If these upper bristles should touch the segment pillars when they are delivering the wool, uneven filling is certain to result, and they must, therefore, be cut so that they never touch anything but the pins of the circle throughout their entire course.

The heads work on two excentrics X fixed with their centres exactly opposite to one another on the barrel shaft, which can be raised and lowered by a rack wheel and the elbow arrangement at their lower extremity. The driving of the rollers from a worm W on the rim of the excentrics is at once simple, ingenious, and efficient, and it imparts a very steady motion to the sliver.

The Square Motion.—As is the case in the nip comb, the principal duty of the circle in the Holden is to hold rather than to clear the wool, and for this reason it has only two rows of pins, which are both flat, the front row having usually 30 and the back row 28 pins per inch. After the wool has been lashed on to the pins, it is carried round by the circle until it comes into contact with the press knife P (Figs. 53 and 54), which is situated between the two rows of the large circle, and is placed there to hold the wool firmly in the pins, whilst the fallers of the square motion clear it. These fallers R R (Figs. 53 and 54) are so set that their pins rise right through the uncombed fringe and at once move away from the circle. At the point 20, where they first catch the wool, the pins are very openly set, and only catch the tips of the fibre; but, as the comb revolves, each succeeding faller gets hold of the wool nearer to the circle, until, at the point where their pins

TABLE XIII

Table Speeds of Holden Comb

Taking the speed of the first shaft as 120, we have the following calculations:—

1. Picks per minute of the filling head,

$$\frac{120 \times 20}{15} = 160.$$

2. Ins. per min. fed by 3-inch feed-rollers,

$$\frac{120 \times 20 \times 1 \times 18 \times 3 \times 3\frac{1}{7}}{15 \times 36 \times 27} = 28 \text{ inches.}$$

3. Inches per minute fed by $2\frac{1}{4}$-inch rollers,

$$\frac{120 \times 20 \times 1 \times 10 \times 2\frac{1}{4} \times 3\frac{1}{7}}{15 \times 20 \times 20} = 28\frac{2}{7} \text{ inches.}$$

4. Inches per minute, drawing-off rollers,

$$\frac{120 \times 76 \times 26 \times 24 \times 60 \times 1\frac{1}{2} \times 3\frac{1}{7}}{81 \times 16 \times 50 \times 25} = 993 \text{ inches.}$$

5. Revolutions of circle,

$$\frac{120 \times 76 \times 1 \times 30}{20 \times 45 \times 242} = 1\frac{1}{4} \text{ revolutions.}$$

6. Inches per minute, traverse of circle,

$$\frac{120 \times 76 \times 1 \times 30 \times 40 \times 3\frac{1}{7}}{20 \times 45 \times 242} = 158 \text{ inches.}$$

7. Inches per minute, square-motion fallers,

$$\frac{120 \times 15 \times 22}{14 \times 22} = 128 \text{ inches.}$$

A comparison of No. 1 and No. 6 shows that each head puts one fringe on to the circle after it has moved 1 inch, and as each fringe is about 3 inches wide, it must overlap the next by 2 inches. That is to say, the pins receive, from the two heads, six separate layers, which make the filling of the circle consequently uniform, as explained in regard to the Lister comb. (Fig. 52.)

Nos. 2 and 4 show that the total draft between the feed-rollers and drawing-off rollers is very large, being $\frac{993}{28}$ or $35\frac{1}{2}$.

No 7 gives the results noted on p. 153

are the finest and most closely set (30 per inch), they rise through the fringe of wool almost in contact with the pins of the circle and pass through the entire length of the staple before they leave it. The fallers are flat horizontally, but curved laterally, so that they have more than tangential contact with the comb, being virtually in contact with the circle for a space of 6 inches. They are of 1 inch pitch, and are all pinned in a very peculiar way with 12 rows, the pins in each row being much farther apart at the end than at the centre, say, 20 pins per inch at A, increasing gradually to 30 per inch at the small curve, the back rows having fewer pins than the front ones, so that the work may be done very gradually and without any damage to the staple.

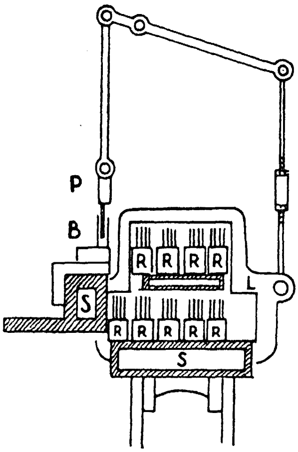
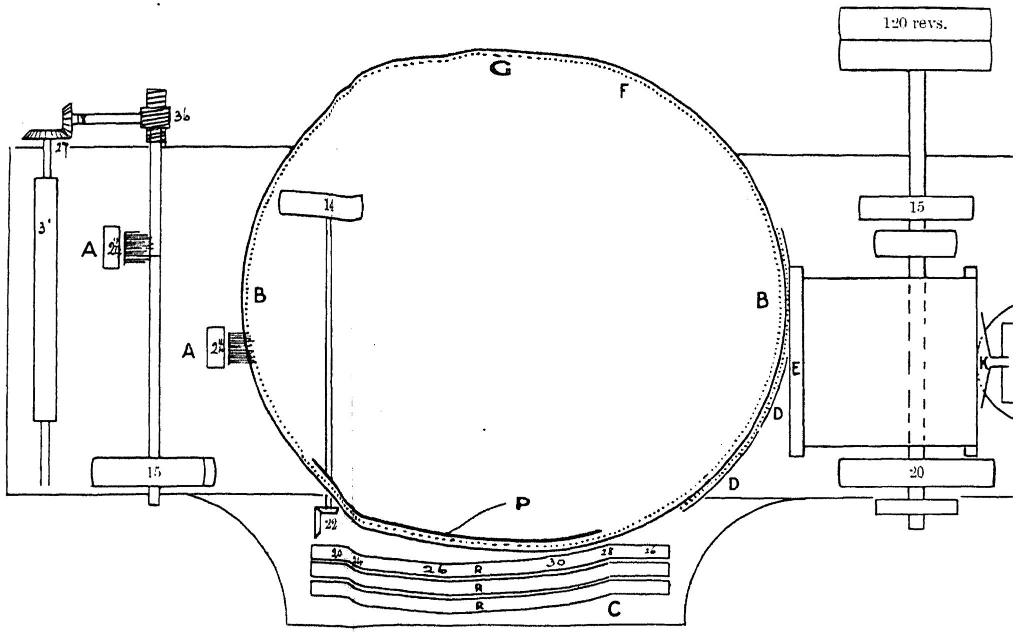


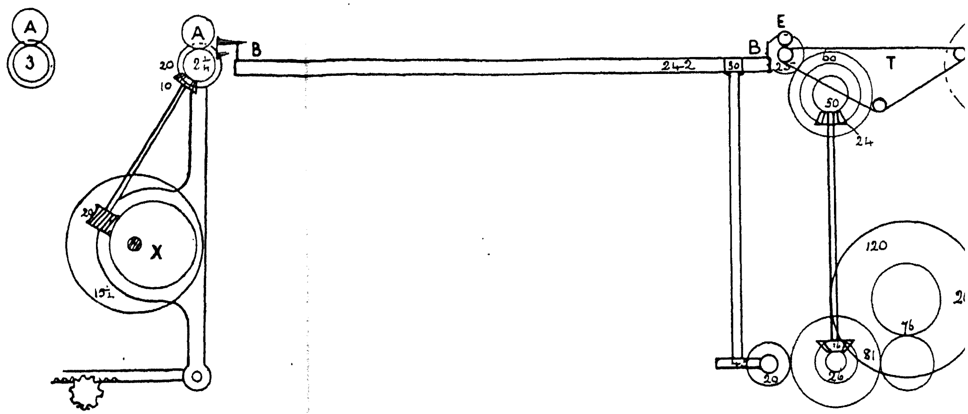
FIG. 54.—HOLDEN'S SQUARE MOTION.

The fallers are actuated by tappets and lifting frames L (Fig. 54), which raise and lower them at a uniform rate to obviate the jar and breakages which would be sure to result if screws and cams were used to move such heavy fallers. There are three slides—one to lift the fallers at one end, a second to lower them at the other end, and a third which both pushes the top row of fallers away from the circle, and brings the low row back to the position from which they can again be lifted. All three must, of course, be worked exactly in time, and it must be borne in mind that the motion of the fallers is intermittent; the top row is stationary when the bottom row is moving, and *vice versa*.

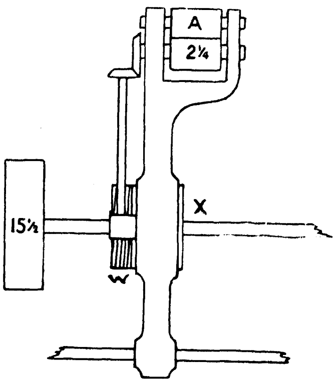
This square-motion combing not only removes every



PLAN



SIDE ELEVATION



SIDE ELEVATION OF FILLING HEAD

FIG. 53.—ELEVATION AND PLAN OF HOLDEN COMB GEARING

To face p

trace of noil, but it smooths and straightens the fibres better than any other process. The fact that this thorough combing comes immediately after the lashing which the fibres receive in being put on to the pins is one of the main reasons for the excellent work which is turned out by this machine.

No system of combing could be arranged in more perfect accordance with theory than is this. Everyone knows that if a long tress of tangled hair is to be combed without being broken, the tips must be straightened and separated before any attempt is made to comb or separate the roots; and if a coarse comb be used first, a fine one can be applied afterwards without any liability to break the fibres. All this is done on the Holden machine. If the working length of the square-motion fallers be taken as 16 inches from the point where they first touch the points of the wool to the place where they leave it, the calculation (page 151) shows that 13 fallers will have risen in that time, and each fibre will have been combed by 13 fallers, or by 156 rows of pins, as each faller contains 12 rows. Both fallers and pins are heated by steam chests SS (Fig. 53).

The Press Knife.—It has already been stated that the circle has only two rows of pins, and the fallers have ten rows each.

When wool of good staple is being combed the fringe will be 3 to 4 inches long, and where the fallers are nearest to the circle the fringe will therefore extend through three or four of them. That is to say, it is being constantly combed by thirty or forty rows of pins at once, and it is obvious that this would pull all the wool out from the two flat rows of pins in the circle and make almost all of it into robbings, if some course were not adopted to prevent it.

For this purpose a patent was taken out in March,

1860 for a "keeping plate" or press knife P (Figs. 53 and 54), which consists of a steel plate so curved that it moves easily in the space between the two rows of the circle. It is worked by levers and connecting-rods, from the lifting slide L (Fig. 54) of the square motion in such a way that when the upper row of fallers is in motion the knife is down, pressing the wool deep into the pins, and holding it firmly against the brass of the circle. The connecting-arms that hold the knife are so jointed and arranged, that it can move freely with the circle whilst it is down, the friction of the wool being sufficiently great to carry it forward; but as soon as the motion of the fallers temporarily ceases, the knife lifts, and whilst the fallers are stationary, it is free to swing back to its original position, and is helped to do so by a spring.

The connecting-rods have a screw adjustment which allows the knife to be raised or lowered according as the circle is more or less heavily loaded with wool. It is of the utmost importance to have the press knife carefully adjusted, for if it be too deep the pressure will tend to jamb the circle and cause it to rock; and if, on the other hand, it be set too high, it will not properly grip the wool, which will be insecure, many of the long fibres will be pulled out of the circle by the fallers, thereby greatly increasing the proportion of robbings, and consequently increasing the cost of the top.

The Segments.—As soon as the circle has moved so far that the wool is clear of the square-motion fallers, the segments come into play.

It was found before the segments were invented, that however closely the square-motion fallers RR were set to the circle B, there was always a quarter of an inch of the fringe outside the circle pins that was never

touched by the pins of the fallers, and it therefore went uncombed to the drawing-off rollers. When the fibres were drawn off there was consequently a considerable proportion of noil knots in the sliver, and the only way to prevent this uncombed portion being drawn through the rollers was to insert another row of pins through the fringe just outside the circle pins, when the wool was being drawn off. These pins must, of course, move at the same speed as the circle, and to make this possible, it was necessary to adopt a very

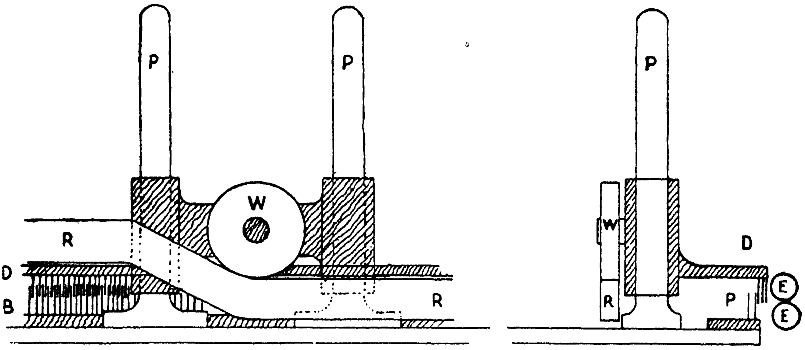


FIG. 55.—SEGMENTS, HOLDEN COMB.

complicated system of combs known as the segments. The motions involved are so intricate that it is almost impossible to make their action perfectly clear to anyone who has never seen a Holden comb, but they may be described as a complete inverted circle about half-an-inch larger in diameter than the main circle, with three rows of pins pointing downwards (D, Fig. 55).

This upper inverted circle is cut into ten pieces or segments, each of which is carried round by two pillars P standing on the rack plate which carries the lower circle, and on these pillars the segment D is free to rise and fall.

Each segment has also a wheel W running on a

circular guide rail R, which keeps the segment about 6 inches above the circle for three-quarters of the complete revolution, but the rail is so curved that just before they come opposite to the drawing-off rollers E (Figs. 53 and 55) each segment is let down in turn, so that its pins pass through the fringe, close to the pins of the circle, enclosing only that part of wool which is uncombed by the square-motion fallers. All the knots are now inside the pins, and when the fibres are drawn off by the rollers E *all* the short wool and noil knots are retained either in the circle or the segments.

As soon as the segments have passed the drawing-off rollers E they at once begin to rise up an incline on the guide rail, and the noil adhering to them is brushed down into the pins of the circle, so that any remaining long fibres may be drawn off by a pair of small "Backing" rollers inside the circle at G (Fig. 53). A few inches farther on the noil is lifted out by a knife, leaving the circle once more empty and ready to be refilled by the heads.

In some modern machines the noil is transferred to another small inverted circle before it is stripped, and the noil is removed to a can from this circle.

The drawing-off rollers are horizontal, making a henwing sliver with all the short wool at one side exactly as in the Lister comb, and as the action is exactly the same in both machines it is unnecessary to repeat the description which was given in the last chapter. After travelling forward on the horizontal table leather T the sliver is collected in a rotating funnel K and is transferred thence to a can coiler L (Fig. 53).

No one can read through these paragraphs without noticing the great number of parts in the Holden comb which need the most accurate adjustment. The filling head and the square motion must both be kept very

rigid and absolutely accurate; and if the smallest accumulation of wool occurs on the press knife, the circle is certain to be injured. If the segments are too far from the circle there is certain to be great loss of tear, and if they are too close there is great danger of locking, so that the fibre will be broken. The cleaning of the square-motion fallers is also a continual source of care and labour.

All these points, however, can be overcome by care, and the number of combs in use proves the thing is possible in practice; but the greatest drawback of the Holden principle is the production of robbings and backings; both have to be taken back to the card and recarded, and as the robbing is the product of the square motion, which is the most important factor in producing the lustre for which the Holden comb is noted, it seems certain that it can never be done away with.

With so many drawbacks, how is it that the Holden comb can still compete so successfully with the Noble machine? For very long and very short wools it is not well suited.

When doing fine or medium qualities of good staple the amount of noil, in proportion to the weights of tops and recombed robbings taken together, may be greater than is the proportion of noil to top from a Noble machine; but, on the other hand, the finished top will often have more length, and it almost always has more *bloom*. If a practical man be asked the reason for this extra finish he will very likely give the laconic reply that "it is due to heat and steel." Let us see what this means in plain English.

In the first place, we must understand what *bloom* means: it is really a kind of lustre. The definition may not be a popular one, but reduced to simple terms it means shine or reflection of light. We have seen that

a woollen thread is dull because the component fibres are never parallel enough for two of them to reflect light in the same direction, and that the fibres in all worsteds are straighter and look brighter in consequence.

The brightest wools not only have large scales, but their fibres are so much straighter that they can lie more nearly parallel in sliver and thread. No amount of combing can alter the size of the scales, but continued movement through the smooth hot pins must tend to make their rough edges or serrations less visible. All combing ought to smooth and straighten the fibres and leave them all in a condition very nearly parallel. It is safe to say that the smoother and straighter the fibres are, the greater is the bloom.

To get the curves or waviness out of any wool it must be stretched thoroughly; by preference it should be stretched whilst hot and left to cool slowly in such a position that the individual fibres cannot resume their original form. All combing processes have this object in view more or less, and the Holden possesses it to a greater degree than any other machine. The first stretching occurs between the filling heads and the circle, and if the motion be imitated by hand it is easy to feel how great is the tension exerted, when the uncombed sliver is drawn away from the pins and the wool which they have taken hold of; here, however, the wool is cold, and very little of it is really drawn through the warm pins, but as soon as it is once on the circle every successive motion of the machine tends in the same direction. The comb circle itself is heated by steam to at least 212° F., the square-motion fallers are at the same temperature (or they may be hotter if heated by gas), and as the segments run round on another steam chest, their pins are very little cooler

than those of the circle. This means that an enormous number of hot smooth pins pass through the whole length of the closely packed moist fibres, and no treatment short of double combing can give such an amount of "work" and consequent lustre to the wool under treatment.

There is one other feature of the Holden process which is well worthy of notice—*i.e.* whichever end first the fibres in the carding are fed on to the circle, they *all* reach the combed sliver with their position exactly reversed; whilst in the Noble comb some fibres are reversed and some are not.

It was at one time claimed that the fibres from a card reached the carding sliver either all point first or all root first, and that the Holden machine made a superior top because it preserved them in the same relative position. But it is clear that this theory is founded on an incorrect assumption, for we have seen that the carded fibres are inextricably blended root to point and point to root before they reach the comb, and therefore, whatever process of combing they go through afterwards, they must lie in both directions in the top.

Hence we can only come to one possible conclusion—that the amount of heat and the number of pins which are brought to bear on the wool are the real causes of the lustre or bloom which is given to nearly all wool treated on the Holden comb.

CHAPTER X

THE NOBLE COMB

In common with the Holden and Lister combs, the Noble comb contains its share of the novelties which Dr Cartwright embodied in his second combing-machine built about 1791, whilst its principles are those on which Mr Donnisthorpe and Mr Noble took out their patent in Noble's name in 1853. In construction the machine has undergone considerable variation, but its essential parts are very little altered since that date.

The working parts are—

A, a large horizontal comb circle with vertical pins (Figs. *57a* and 68).

B, one or more inner circles, the outer pins of which touch the inner row of pins of the large circle.

C, a dabbing-brush to drive the wool down into the pins at the point of contact.

D, vertical drawing-off rollers.

The various patents which have been taken out and embodied in the machine from time to time are so numerous that reference cannot possibly be made to nearly all of them, and only those which form essential features in the comb of the present day will be noticed, except in cases where the part as at present used is a development of some previous device. As a photograph of a complete combing-machine, Fig. 56, gives little or no idea of the details of its working parts, the construction of the machine will be illustrated by sections.

In principle, the Noble differs from all other combs in having comb circles as its only means of clearing

the wool and for taking out the noil, and it is this simplicity of principle that makes the machine so great a success in practice. It also differs visibly from all other machines in that the moving circle carries round with it, on a creel, the whole of the carding balls which are being combed. These, as already stated, are made up by the punch-box, with four parallel slivers in each ball; 18 balls or 72 ends making a complete set, which may weigh anything from 200 lbs. to 350 lbs., depending on the quality of wool and the size and construction of the balls.

In Fig. 57 the whole of the upper gear as well as the drawing-off rollers and the creel are removed, so that the relative position of the circles, which are the most important parts of the machine, may be clearly seen. The large circle is $42\frac{7}{8}$ inches in diameter, measured on the points of the inner row of pins, and the small circle is 16 inches in diameter, measured on the points of the outer row of pins. Both these circles rest on racks, the outer one having 264 teeth and that for the inner circle 94 teeth. They are coupled through two small shafts, carrying wheels of 10, 13, 16, and 11 teeth respectively, which give a surface traverse approximately equal on both circles. This means that at the point of contact the circles are stationary in regard to each other, and the wool can be dabbed down as easily into one as into the other. The essence of the whole comb lies in the fact that the pins of the two circles draw apart as they travel round, without otherwise altering in their relation to one another, and it is in this separation of the two combs that the efficiency of the Noble combing depends; because the short wool and knots are all stamped down by the brush into one or other of the circles, where the pins of the two circles are in contact. In fine circles with pins set 46 or even

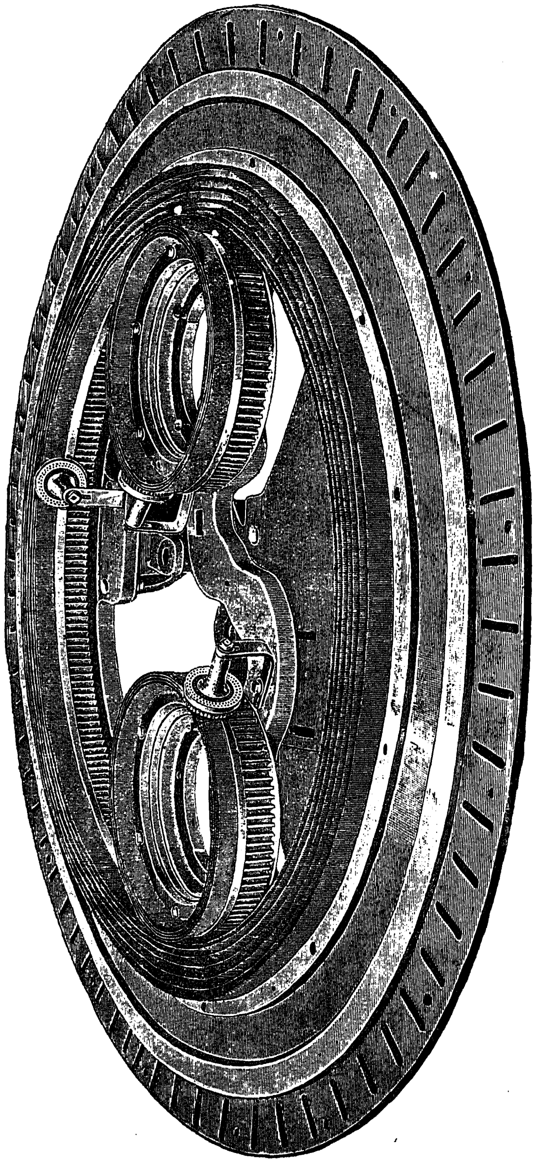


FIG. 57.—CIRCLES, RACKS, AND RACK PLATE OF NOBLE COMB SHOWING POINTS OF CONTACT AND CLEARING BRUSHES.

48 per inch, there is a space of less than $\frac{1}{100}$ of an inch between each two pins, and, as no knots or vegetable matter can get through these fine spaces, the fringes of wool which hang from both circles after their separation are quite straight and free from knots. In other words, it is the size of the spaces between the pins and not the number of pins per inch which is essential to secure the best possible work. (See footnote, pages 164, 165, 166.)

After the large circle has travelled about a quarter of a revolution, and half a revolution in the case of the small circle, both fringes reach their respective drawing-off rollers DD. The fibres in the clean fringes are stroked forward to the roller, so that they all go to the nip point first, and as the circle moves round, the fibres in every succeeding portion of the fringe are drawn right out of the pins by the rollers, leaving behind them all wool which was too short to reach to the nip from the outer row of pins, and leaving quite within the pins all knots and burrs. In the small circle there is now nothing left but this mixture of short wool and knots, which is known as noil, and as the circles rotate this is lifted out of the pins by stationary inclines or knives at N, between which the rows of pins move. When the noil reaches the top of the pins it falls over into a funnel prepared for it, and the circle is then ready to be filled again, when it reaches the point of contact with the large circle.

Clearly, there is only one point at which pins of the two circles touch one another, and as the sliver at that point is crowded with knots, some of them will be outside both circles if the fibres are pressed down into the pins after they reach the point C (Fig. 57*a*). In that case the knots would emerge at X and go through the rollers into the sliver. On the other hand, if the wool is dabbed in at Y, exactly the same thing will happen.

TABLE XIV

Particulars of Circles for Noble Combing Machines

For 64s Super Australian.

Large Circle.				Small Circle.			
No. of Rows.	Pins per in.	Size of Pins.	Open Space.	No. of Rows.	Pins per in.	Size of Pins.	Open Space.
			Inches.				Inches.
1	41	17 × 27	·344	1	46	18 × 28	·333
2	40	18 × 27	·360	2	45	19 × 28	·348
3	39	19 × 27	·376	3	40	20 × 27	·360
4	36	21 × 26	·352	4	36	21 × 26	·352
5	28	23	·300	5	28	23	·300
6	27	23	·325	6	27	23	·325
7	23	22	·356	7	23	22	·356
8	20	21	·360	8	20	21	·360
9	20	21	·360	—	—	—	—
10	17	19	·354	—	—	—	—
11	14	18	·384	—	—	—	—
Flat rows 4 Set over $1\frac{3}{4}''$ Brass $\frac{7}{16}''$ thick $2\frac{3}{4}''$ wide Length of pins $1\frac{5}{8}''$				Flat rows 4 Set over $\frac{5}{8}''$ Brass $\frac{3}{8}''$ thick $1\frac{3}{4}''$ wide Length of pins $1\frac{3}{8}''$			

The figures in columns 4 and 8 indicate, in decimals of an inch, the total space in every inch which is not occupied by pins, and if the figure is divided by the number of pins in one inch, it will give the space between every two pins in the row. For instance, ·344 in. ÷ 41 = ·008 in. or $\frac{1}{120}$ in., which is the space between the pins in the front row. The

TABLE XV

PARTICULARS OF CIRCLES FOR NOBLE COMBING MACHINES

For 50s Crossbred.

LARGE CIRCLE.				SMALL CIRCLE.			
No. of Rows.	Pins per in.	Size of Pins.	Open Space.	No. of Rows.	Pins per in.	Size of Pins.	Open Space.
			Inches.				Inches.
1	33	16 × 25	·340	1	37	16 × 26	·334
2	32	17 × 25	·360	2	36	18 × 26	·352
3	28	18 × 24	·356	3	32	18 × 25	·360
4	24	22	·328	4	24	22	·328
5	20	21	·360	5	18	20	·370
6	18	20	·370	6	14	18	·384
7	18	20	.370	—	—	—	—
8	14	18	·384	—	—	—	—
9	12	17	·376	—	—	—	—
10	12	17	·376	—	—	—	—
Flat rows 3 Set over 2½″ Brass ½″ thick 3½″ wide Length of pins 1⅝″				Flat rows 3 Set over ⅝″ Brass $\frac{7}{16}$″ thick 1¾″ wide Length of pins 1½″			

figures for each succeeding row are ·009—·010—·011—·012—·015—·018—·018—·021—·027. That is to say, in a properly made circle, the space between the pins increases steadily in each succeeding row, and if the wool is to be drawn without any tendency to break, it is most important that this arrangement should be followed.

TABLE XVI

Particulars of Circles for Noble Combing Machines

For 40s *Hoggs*

Large Circle.				Small Circle.			
No. of Rows.	Pins per in.	Size of Pins.	Open Space.	No. of Rows.	Pins per in.	Size of Pins.	Open Space.
			Inches.				Inches
1	22	13×22	·384	1	24	13×22	·328
2	20	14×21	·360	2	23	15×22	·356
3	18	15×20	·370	3	18	16×20	·370
4	13	17	·324	4	13	17	·325
5	12	17	·376	5	11	16	·351
6	10	15	·360	—	—	—	—
7	8	14	·440	—	—	—	—
8	7	13	·426	—	—	—	—
9	5	13	·590	—	—	—	—
Flat rows 3 Set over 4″ Brass $\frac{9}{16}$″ thick $4\frac{1}{8}$″ wide Length of pins $2\frac{1}{8}$″				Flat rows 3 Set over $\frac{1}{16}$″ Brass $\frac{9}{16}$″ thick 2″ wide Length of pins $1\frac{7}{8}$″			

There is always a considerable fall from the last flat row to the first round row, because the round pins are thicker, and if they were not set more sparsely there would be too little space between them. For instance, if there were 33 pins instead of 28, of 23 wire in the 5th row of Table XIV., there would be a total space of only ·125 in., or ·005 in. between every two pins, and there would therefore be greater strain in that row than there is in any other.

The same method of calculation applies to all three types of circles.

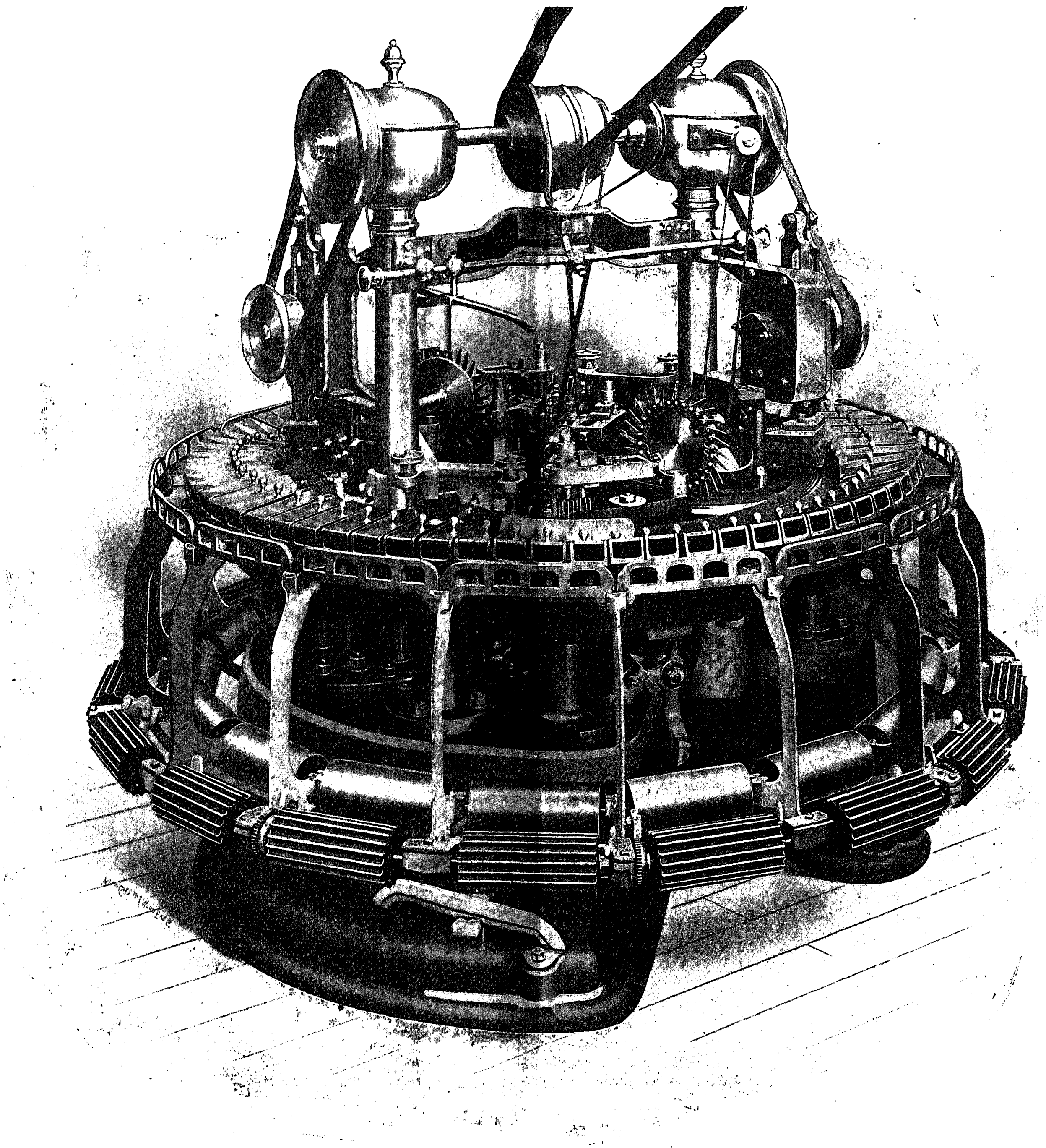


Fig. 56.—Noble Combing Machine by Messrs. Taylor, Wordsworth and Co.

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The wool must first be touched by the dabbing-brushes *just as it reaches the point of contact*, but the dabbing-brush may extend well over the point X to keep the wool from rising over the points of the pins as the circles separate. This brings us to dabbing-brushes and their speeds.

Dabbing Motions.—If a $42\frac{7}{8}$-inch circle be travelling $3\frac{1}{2}$ revolutions a minute, the inner rows of pins will

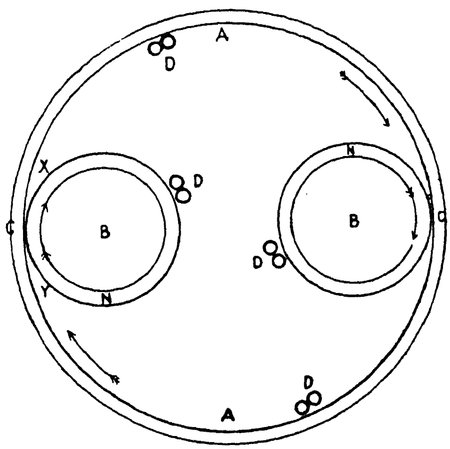

FIG. 57*a*.—PLAN OF NOBLE COMB.

move 459 inches per minute (see Table XVII., p. 182), and with a dabbing-brush running at 750 revolutions per minute this would mean that the circle travels more than half-an-inch for every dab of the brush. If wool were put in by the brush at one dab, exactly on the point of contact, the next fibres would have travelled half-an-inch past the point of contact towards X before the brush came down again. In that half-an-inch the circles will have separated somewhat. Theoretically, there will be room for knots to get down between the pins and make imperfect work. For this reason it is important for the brushes to move very quickly

The wear of the brush bristles is also affected by the speed of the dabbing. From the nature of a stroke imparted by a crank-pin, the brush will be in the pins for about a quarter of the total revolution—that is to say, the pins will move at least $\frac{1}{8}$ of an inch through the bristles every time they are down; and great attention has been given to the construction of rapid dabbing motions, in order that every fibre may be put into the pins within $\frac{1}{4}$ of an inch of the right point, and also that the amount of movement of the pins through the bristles may be as small as possible.

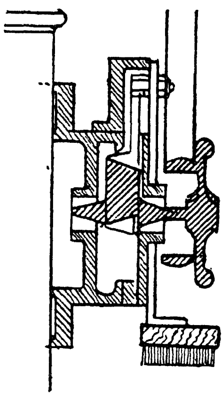

FIG. 58.

The early dabbing motions were moved by a simple crank-pin and connecting-rod, which may have been efficient for the slow speeds at which combs were run in those days, but with the demand for more speed the crank motion disappeared and was replaced by Speight's patent balanced excentric motion. This was a distinct advance, and when all the fittings were tight it could be run up to 700 dabs a minute without undue shake; but the short parallel bearings wore away rapidly, the cost of repairs was heavy, and when not kept in the best order the vibration at any speed over 500 was sufficient to shake the whole comb. About twenty years ago, Lister Batty's enclosed cam or excentric motion was brought out, and since that time it has taken almost universal precedence. Fig. 58 shows that it is entirely enclosed in a case, the lower part of which contains enough oil to touch the cam at every stroke, in such a way that the oil is splashed on to every portion of the mechanism, and thorough lubrication thereby insured. The patentees wisely

recognised that if great speed were to be attained without undue wear and tear there must never be any shake in the bearings; and to make up for the inevitable reduction by friction, which must always be present in bearings, the excentric and the bearings were all made long and conical. The bearing cones are set so far apart that twisting is practically impossible, and they are made adjustable by screws on the outside of the case. It is therefore easy to keep the parts entirely free from jar even when they are working at high speeds.

The only important modification which has been made since this type of motion was introduced is made by Prince, Smith & Sons, and it not only has its excentric A (Fig. 59) balanced in the ordinary way, but the balance takes the form of another excentric B, carrying a second slide C, which does no work, and only acts as a perfect counterpoise. As the brush and its slide descend, the balance-slide rises, and *vice versa*. The makers claim to secure such perfect balance in this way that they can safely run at speeds of 1200 dabs per minute without any excessive vibration, and as every increase in the speed of dabbing increases the theoretical perfection of the work, it is a step in the right direction.

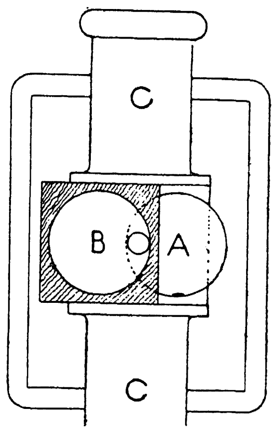

FIG. 59.

Dabbing-brushes are not by any means the only method which has been tried for pressing wool into the pins of a comb. The great cost of keeping brushes in repair has induced many inventors to try and do without them altogether. Revolving steel discs have been tried by some, instead of brushes, and others have

tried blasts of air at high pressure. Unfortunately, the discs always tended to drag the wool backwards, and under an air blast the fibres always tried to escape sideways from the very point where it was most necessary for them to go into the pins. It is true that the cost of keeping brushes in repair is a serious item of expense wherever Noble combs are used, and any successful method of efficiently putting wool into the pins without brushes would therefore be a great saving, but as yet nothing has ever been found which in practice can compete at all with a good dabbing motion.

The Conductors.—A cycle of operations is completed by the large circle, at the end of half a revolution, and

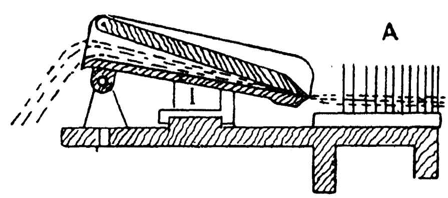

FIG. 60.

we must follow the operations until that point is reached. To understand the next movements we must begin again at the beginning. The balls from the punch-box stand on rollers H, which hang from the outer edge of the rack (Fig. 68), and they are, therefore, carried round, without any further mechanism being necessary, at the same speed as the circle. At every revolution of the comb a cam moves the rollers on which the balls stand and pays out the necessary amount of sliver. It now only remains for the machine to lift the sliver out of the pins, pull up the slack sliver, and lay the end right over the pins of the small circle. It is the conductors which do this work. They are a series of 72 brass troughs (see Fig. 60) made fast to the rack plate R (Fig. 68, facing page 182) with lids hinged at the

outer end, so that they nip the wool at the end close to the circle and allow the sliver to be pulled forward easily, towards the circle, but prevent it from slipping back by the manner in which the lids hang. The conductors are also hinged so that their inner ends can rise and fall. For the greater part of a complete revolution they rest on the rack; but a few inches past the roller there is a stationary incline I, up which the conductors must rise as they travel forward, whilst the slivers are held tightly down in the pins by the press knife P. The height to which this knife is set determines the amount of sliver drawn forward, because the conductors always rise to the same height at every revolution. As the

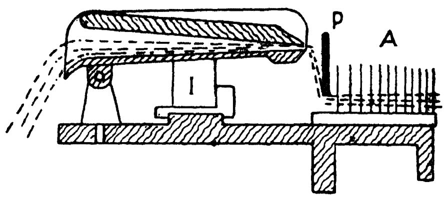

FIG. 61.

sliver passes the rollers it lies in the conductor and circles in a straight line as shown (Fig. 60); but when the conductors are on the top of the incline the position has altered (Fig. 61), so that there is an inch more sliver between the nip of the conductors and the pins than will reach across the pins of the large circle A. The knives K now lift the sliver out of the pins, and as the conductor lid prevents the sliver from slipping back, the sliver falls forward over the steel plate which covers the pins at this point, and lies with its extremity over the pins of the small circle B (Fig. 62).

As was stated in Chapter VIII., the arrangement of short and long fibres in a carded sliver does not appear to be uniform, when the sliver is broken, the short end having the short fibres nearer to its extremity than is

the case with the long end. This peculiarity is due to the action of the doffer, and must be considered if the best results are to be obtained in the comb. To get the greatest proportion of top with the least quantity of noil from any carding, the short end must be fed up first to the comb, so that when it reaches the position of Fig. 62 the bulk of the short wool will be stamped into the small circle without any fibres overhanging its inner row of pins. If the long end were fed up first the bulk of the short wool would be at least half-an-inch from the end of the fibres; or, in other words, when the short wool was in the pins of the small circle B there would be a heavy fringe of longer fibres within

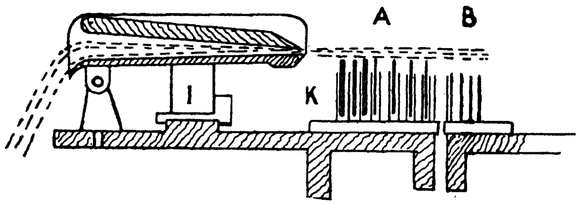

FIG. 62.

its inner row of pins, and all this longer wool would be taken off with the noil, and so wasted.

Drawing-off Rollers.—It was explained in the chapter on Preparing that fluted drawing-off rollers always cut the wool unless they have a leather between them to act as a cushion, against which the wool is nipped. If leathers were durable, the necessity for using them would be no great drawback, but unfortunately they soon wear out. This is due, first, to the severe bending strains to which they are subjected every time they go through the rollers, and secondly, to the wear caused by the action of drawing the fibres through the pins. The combined effect of drawing and bending always wears a leather away in the middle, where the greatest

proportion of the strain comes, and as the endless leathers have to be made with a spliced glue joint, they most often wear at the joint first. Where only one of the rollers is driven by wheels the other is moved by the friction of the leather, and this friction naturally wears the leather at every place where it is pressed between two flutes. In the early days both rollers were never driven, but some firms have recently adopted the plan of cutting a small pair of toothed wheels on the two-roller shafts, below the flutes: these do the driving of the second or pressing-roller, and greatly lengthen the life of the leather by relieving it of a very large proportion of the friction.

In the original system of putting pressure on to the rollers, short bushes and short springs were used, which allowed a certain amount of sideplay in the free roller. When the rollers were not exactly parallel through unequal pressure or on account of the position of the wool, the leathers were found to wear very quickly, and to minimise this wearing several very ingenious devices have been adopted. Under Jowett & Sharp's patent, pressure was applied from one screw to two levers (Fig. 63), the ends of which rested on both the top and the bottom springs and gave exactly equal pressure to both, even when both springs were not exactly of the same strength. This was a considerable improvement; and when the bushes which hold the outer roller were lengthened and made to fit accurately in the stand, it increased the life of the leathers very considerably. Messrs Prince, Smith & Sons and Messrs. Hoyle & Preston have both taken out patents with a view to keeping the pressure uniform by keeping the bushes of the pressing-roller always at right angles to the driving-roller. In the type made by the former firm the weight is applied by two springs at the top and two at the bottom, as shown in Fig. 64, and as

the blocks carrying bushes are carefully milled, it is very difficult for the rollers to get away from a parallel position, and the length of life of the leathers is therefore considerably increased.

In the old machines the steam-chest formed the frame to which the roller stands, and nearly all the

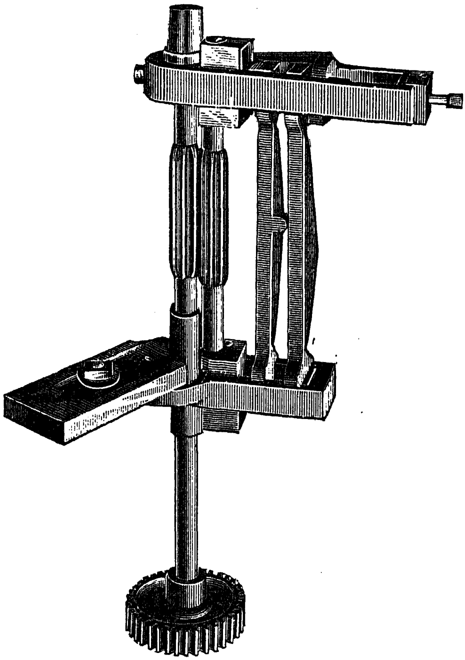

FIG. 63.

other working parts of the comb were fastened. By this arrangement the roller stands were always heated, the expansion and contraction which resulted was apt to loosen bolts, and it also made any alterations very uncomfortable work for the overlooker. In all modern machines the arrangement is quite different, the rollers being supported by a capstan fixing which stands on bed-plate without any connection with the steam-

chest (Fig. 68), and is so arranged that by loosening a couple of nuts the rollers can be swivelled in any direction.

The rollers, like the leathers, wear first at the point where the draw takes place. To minimise this wearing Messrs Taylor, Wordsworth & Co. make a roller in which the fluted portion only revolves on a stationary spindle, and as this prevents all wear in the bushes at the top and bottom, the spindle is always maintained vertical, and they claim that there is therefore an absence of bad work and worn leathers due to unequal pressure.

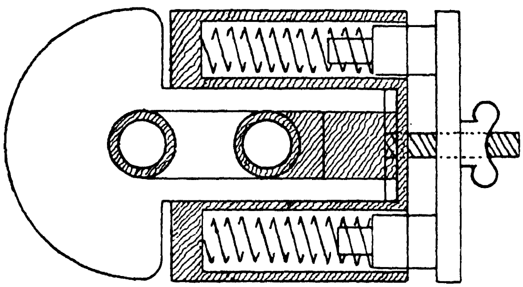

FIG. 64.

Leather Motions.—If the leathers were always to run at exactly the same height, it is clear that the draw would always wear them just at one point in their breadth; that part would not be more than half-an-inch wide, and would very soon be worn right through, whilst the remaining three inches would be unused. Many devices have been invented to move the leather up and down, and so to distribute the wear over the whole of its breadth. Many years ago Ballinson introduced drawing-off rollers which rose and fell as they rotated, but the excessive wear and tear made them too expensive to be of practical value. Other motions have aimed at making the leather only traverse, but very many of them have been complicated and cumbersome.

The leather guides on all four pairs of drawing-off rollers are now almost always controlled from a single shaft, fixed above the bed-plate and carrying hearts which raise and lower the leathers, as the shaft rotates. The shaft may either be driven by a cam action from the rack or direct from one of the shafts, by a series of worms and wheels: both methods are simple and effective, and make it very easy to alter the speed of the traverse if necessary.

The steam-chest in old-fashioned combs was not only the means of heating the rack, but also the sole means of steadying it, and when either the rack or the steam-chest was worn the rack had to be packed with brass wedges to keep it true. It must be remembered that not only the weight of the rack itself has to be driven round by the gearing, but when there is a full load in the creel, there may be 300 pounds of wool in addition, as well as the creel and its fixings, so that if the rack ever touched the steam-chest through the wearing of the whorls, the accumulation of oil, or other cause, the friction was so serious that the driving-rollers often broke. The essentials for a perfect rack and rack motion are—

1. That it should be rigid, so that the circles may always be true at the point of contact.
2. That it may be easily driven, no matter how much weight it may be carrying.
3. That it can be effectively heated in the right place without communicating heat to other parts.

The most recent method of attaining these ends is the use of ball bearings. In the simplest system a semicircular groove is cut in a special carrying frame, which rests on the frame or pillars. This groove is filled with hard steel balls. The upper half of each

ball takes its place in a similar semicircular groove, cut in the rack plate, which entirely prevents any lateral movements, and at the same time makes the circles very easy to drive. Messrs. Hoyle & Preston use a combination of balls, and rollers set at an angle. The rollers have a wider bearing than the balls, and they are supposed, therefore, to hold the rack still more steadily. Both systems do very good work, and both are effective in making the rack very true and saving a great deal of the power which was necessary to drive the rack before they were introduced. The true running of the rack makes it possible to place it very near to the steam-chest, without any chance of undue friction, so that the greatest possible amount of heat is transferred to the pins without loss. (See Fig. 68.)

No satisfactory theory has been established to account for the effect of heated pins on the wool, but the question is dealt with at some length in Chapter IX., and the results in practice are well known. All wool fibres draw more easily when heated than when cold, and if they are drawn through many hot pins or many times through fewer pins, they become straighter and apparently smoother; and if they are kept in ball form, so that they cannot again contract, they set permanently in this way. The hot pins may, in fact, be said to act on the fibre much as a hot flat-iron acts on starched linen.

In outward appearance the Leeds comb of 1903 (see Fig. 56) differs from all other previous and present Noble machines, because the pillars are set outside instead of inside the small circles. This important alteration is a departure from the design originally adopted by Donnisthorpe, which has been followed by every other maker since his time. The new arrangement has three advantages—

1. The circles are easy to get at for small repairs, and when they have to be changed it is only necessary to take off the dabbing-motion support, lift out the knives, and take out the comb screws.

2. The large circles can also be taken off, without removing the pillars, by simply removing the knives and the press knife and loosening the screws. In a test recently made in the presence of experts, it was shown that a running machine could be stopped and have its circles taken off and laid on the floor, within five and a half minutes. This means a wonderful saving of time when compared with the usual method of taking out the pillar bolts, removing the wheels under the plate, and drawing up the pillars with blocks.

3. The noil, instead of falling on the outside of the circle, now falls inside it, into cans or, in the best arranged sheds, direct into bins in the cellar underneath. To make the noil turn to the inside of the circle, the highest knives must be between the finer or outer rows of pins, thus lifting first the edge of the wool most likely to hold in the pins, and keeping the outer row of pins clean and ready to do good work.

Critics say that the long overhang of the bracket which carries the brush motion is likely to increase vibration; but as there is a fixing or foot to support it, it is difficult to see how undue vibration can occur, and the new position of the brush makes it possible to use a diagonal belt, which is a distinct advantage. In this comb also the circle-driving gear is placed behind instead of in front of the small rollers, and all dust and chives which are loosened when the wool is being drawn by the separation of the circles fall out on to the bed-plate instead of on to the wheels.

Circle Cleaning.—Knots and small pieces of vegetable matter in the wool are always very apt to get jammed

between the fine pins in the front rows, in such a way that they force the pins apart and make a gap through which other knots or chives can go to the sliver. Circles with 46 or 48 pins per inch have to be made with pins so fine that they are easily bent, and if they are not continually cleaned they do worse work than combs with fewer and stronger pins. The best way to deal with this difficulty is to use a brush, which is continually pushing the knots and chives up the pins, and so preventing them getting fast near the brass. The oldest type of motion used for this purpose was called a monkey brush, which, by means of a crank, gave an elliptical motion to a long connecting-rod which carried a brush. It brushed the wool and chives from the pins on the upstroke and came down at a distance of half-an-inch or more from the comb. As it gave two brushes to every inch of comb that passed it, it kept all the pins very clean, but the three small belts necessary to drive the three cranks were a distinct disadvantage.

Messrs Greenwood & Farrar's patent rotary brush obviates all necessity for special driving. It is circular (see Fig. 57), with bristles parallel to its axis: it is so fixed that the upper bristles press against the pins of the circle, at such an angle that the movement of the circle causes the brush to rotate. By this rotation the front row of pins are so effectually brushed, that no seeds or burrs can remain between them. In practice the motion is found to work very efficiently, and it has been largely adopted on account of its simplicity.

Framework.—The peculiar way in which the creel of a Noble comb revolves round the entire machine has made it necessary to put the driving pulley high up, so that neither the belt nor the pulley prevents the operative from getting to any end, at any point on the creel. With the strain of a pulley so high above the

floor there is naturally a great tendency to vibration, and two methods have been adopted in the new machines to prevent it. Taylor, Wordsworth & Co. are making their bed-plate, which carries the gearing, all in one piece with a shell, which rests on the foundation plate, and is so bolted to it that even if the floor gave way a little the whole machine would move bodily, and individual parts would retain their relative positions. Prince, Smith & Sons obtain rigidity by spreading the legs of the bed-plate at such an angle that they are neither vertical nor parallel to one another. (See

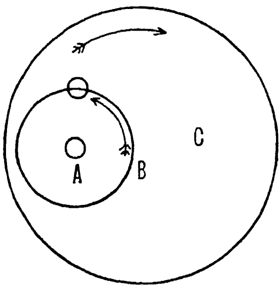

FIG. 65.

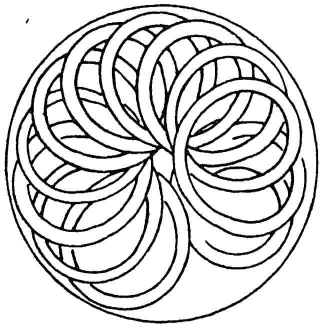

FIG. 66.

Fig. 68.) They also mill all joints on the machine, and put squared faces on the pillars to take the dabbing-motion fixings.

Can Coiler.—The object of putting wool into a can instead of on to a ball is to have it in a condition from which it can most easily be drawn, without any fibres adhering to other parts of the sliver. In all balls there are some places where the fibres lie exactly parallel, and when this is the case there is the greatest chance for the serrations of one fibre to adhere to those of the next. If loose sliver, such as that from a card or comb, were run into a large square can, like those used

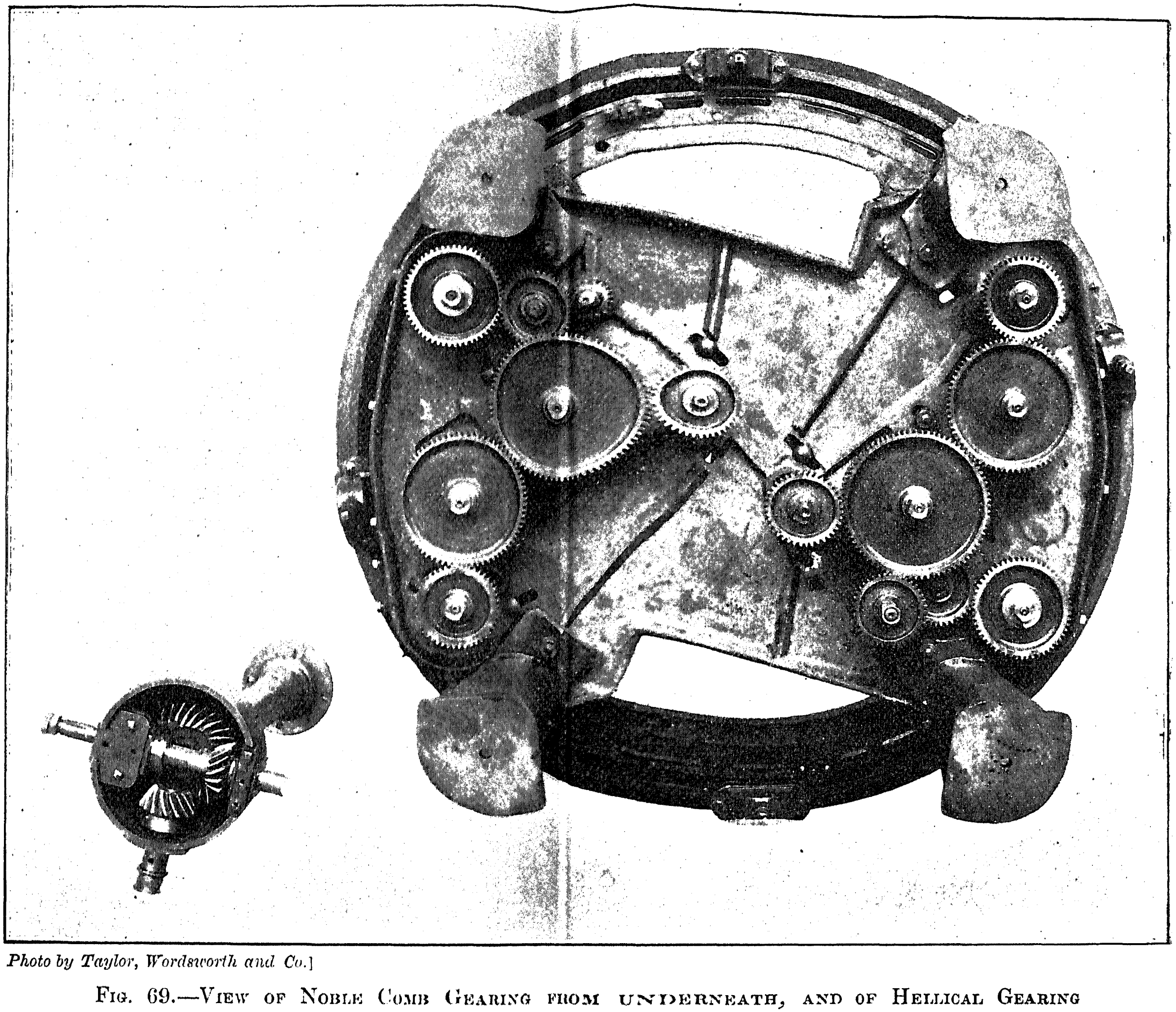

Photo by Taylor, Wordsworth and Co.]

FIG. 69.—VIEW OF NOBLE COMB GEARING FROM UNDERNEATH, AND OF HELLICAL GEARING IN PILLAR HEAD

To face page 180

at a backwash machine, it would tend to lie across the can, backwards and forwards, in layers so nearly parallel that they would not easily separate again. The coiler is designed to obviate all chance of such arrangement. It is usually driven by a shaft and bevel wheels from under the comb, so that the comb and the coiler must stop and start exactly at the same time, the sliver being so tender that it would be instantly drawn apart if the feed-rollers of the coiler ran for a quarter of a second longer than the drawing-off rollers of the comb. Both must stop and start together, and both should run exactly at the same speed. The wool is coiled by three distinct motions—

1. There is a rotary funnel, which rolls the sliver into rope form, but does not put any real twist into it.
2. A rotating disc, which receives the sliver at its centre A, Fig. 65, and as it revolves passes the sliver into the can on the line B.
3. This line is excentric with the circumference of the can C, and as the can is also revolving, the sliver is paid into it, in such a way that it lies in regular coils, as in Fig. 66, with hardly any two fibres parallel and contiguous. From these cans the softest sliver can easily be lifted to the next process without fear of breakage or tearing.

It was once the custom to make the sliver into balls from the comb, but the fourfold sliver having no real twist in it is very tender, and it was therefore found far better to run it into cans, because there need be no strain whatever on a sliver in the process of putting it into a can. The can-head rollers may either be made to deliver exactly the same length as the drawing-off rollers, or there may be just enough draft on them to keep the sliver nicely stretched. In a balling head,

TABLE XVII

Calculations of Speed for a Noble Comb

The Top Shaft in all cases running at 594 revolutions per minute.

1. Revolutions of the large circle (A),

$$594 \times \frac{16 \times 20 \times 10}{32 \times 66 \times 264} = \frac{75}{22} \text{ or } 3\tfrac{1}{2} \text{ revs. per min.}$$

2. Traverse of large circle (A),

$$594 \times \frac{16 \times 20 \times 10}{32 \times 66 \times 264} \times 42\tfrac{7}{8} \times \tfrac{22}{7} = 459 \text{ ins. per min.}$$

3. Traverse of small circle (B),

$$594 \times \frac{16 \times 20 \times 13 \times 12}{32 \times 66 \times 16 \times 94} \times 16 \times \tfrac{22}{7} = 469 \text{ ins. per min.}$$

4. Speed of dabbing-brushes (C),

$$594 \times \frac{15}{9} = 990 \text{ strokes per min.}$$

5. Output of $1\frac{1}{4}$ ins. drawing-off rollers (D),

$$594 \times \frac{16 \times 40}{32 \times 50} \times 1\tfrac{1}{4} \times \tfrac{22}{7} = 933 \text{ ins. per min.}$$

A comparison of Nos. 2 and 3 shows that the small circle overruns, the large one by 1 in 45. This lead keeps a slight strain on the fibres, but it means that, when the circles have travelled forward, the fibres must be drawn diagonally through the pins of the small circle. If the large circle had a slight lead, there would be less strain on the fibres, because they would be drawn radially through the pins of both circles. (See p. 163.)

No. 4 compared with No. 2 shows that the circles move half-an-inch every time the brush dabs. (See p. 167.)

The total draft of the comb cannot be stated accurately. With the two press knives set to draw 1 inch, the total draft *might* be stated as 933 is to 2, or 466, but as each of the seventy-two slivers only forms a very short portion of the total length of 933 inches, it is not a fair way of stating the case.

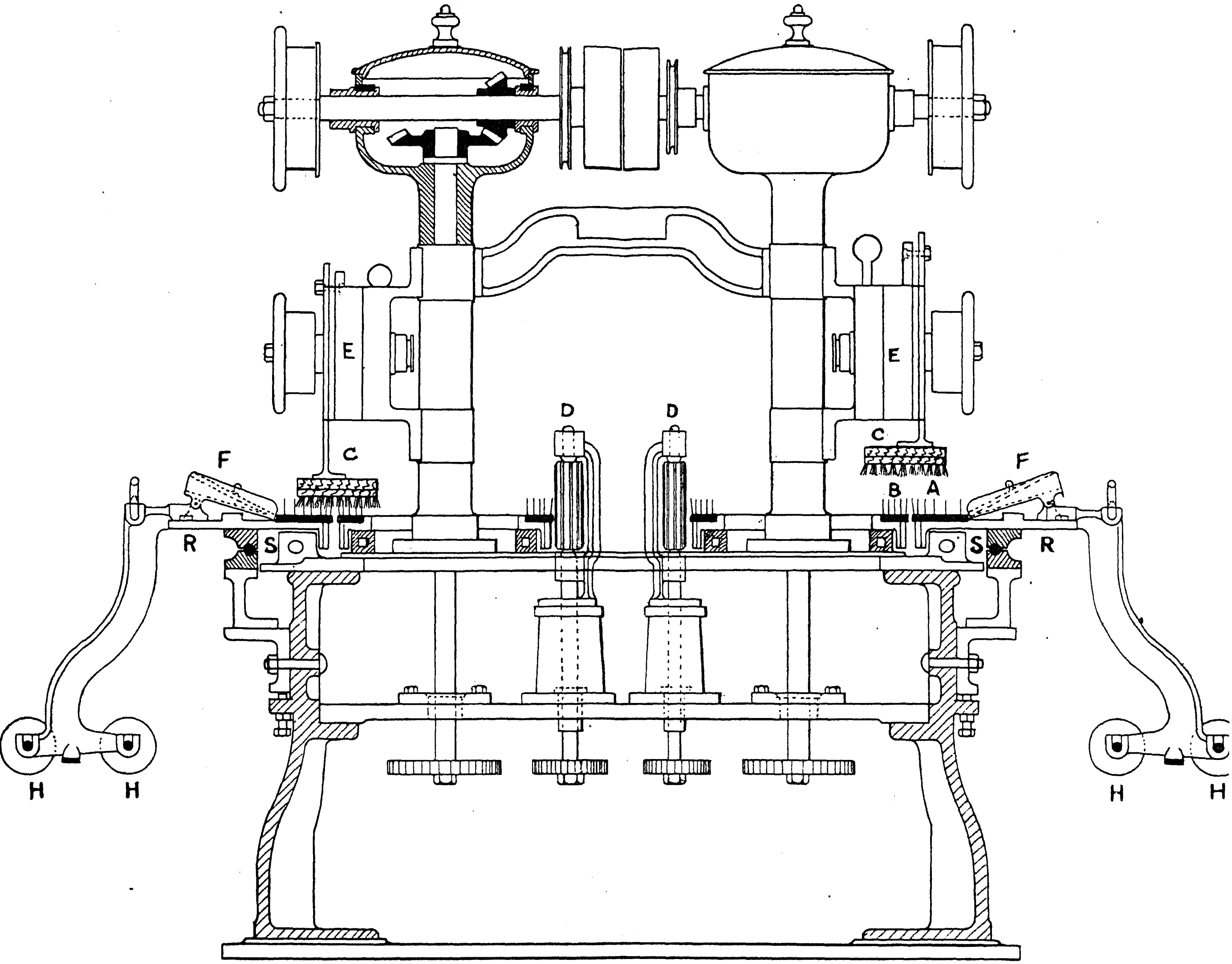

FIG. 68.—SECTION OF NOBLE COMBING MACHINE BY MESSRS. PRINCE, SMITH AND SON

A, Large circle; B, Small circle; C, Dabbing brushes; D, Drawing-off rollers; E, Dabbing motion F, Conductors; H, Creel rollers; R, Rack-plate; S, Steam chests
● Ball bearings

on the other hand, there must be some drag, if the ball is to be sufficiently firm to hold together; but it is not in the building of balls or the filling of cans that the difference in the two methods is apparent; it is the fact that the sliver comes out of a can more easily and more freely than from a ball that makes the use of cans so advantageous.

The gearing of the Noble comb has been reduced to great simplicity in recent models. The old-fashioned double stud gear, which was so difficult to adjust accurately, has been done away with, and simple trains of wheels have been substituted. (See Figs. 67 and 68.) The two intermediate wheels 60 and 65 are connected by links with the wheels on the drawing-off roller shafts, and by this arrangement the wheels always remain correctly in gear, no matter how much the rollers may be moved to or from the circles.

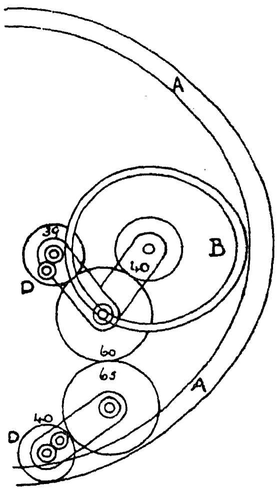

FIG. 67.

The speeds of the rollers vary very much according to their size and the quality of wool being combed. In Table XVII. the rollers are taken as $1\frac{1}{4}$ in. diameter for fine Botany wool. $1\frac{1}{2}$ in. or $1\frac{3}{4}$ in. rollers would be used for medium qualities, and 2 in. or $2\frac{1}{4}$ in. for very long wool. The speeds of circles vary from $3\frac{1}{2}$ to 4 revolutions per minute according to the opinions of individual combers.

The speeds of dabbing-brushes should always be kept as high as possible.

CHAPTER XI

THE HEILMANN COMB

Exactly why the Heilmann Comb is so little known in this country it is difficult to understand. It is true that seventy years ago Mr. Lister paid £30,000 for the English patent rights which covered the French comb and the nip principle. In the words of Mr. Burnley, written in 1889, he was then in the position, either to let the trade have the Heilmann Comb as it stood, or he could sink it in favour of his own nip machine. He elected to do the latter, and for a few years had great success with his English patents. But this did not give him the right to introduce his nip comb into France, neither could Mr. Holden do so until the latter, in 1858, removed all competition by purchasing the whole of the Heilmann interest for France. From that time the French comb began to fall into disuse in the country of its origin, but, on the other hand, perfected by the genius of Schlumberger, it held the field in Germany for many years. Patents, however, do not last for ever, and our insular prejudice must have something to do with our extraordinary ignorance regarding the Heilmann Comb for a period extending over half a century. It must be remembered that the Heilmann machine will comb cotton, a feat that none of the better known machines will perform. In spite of this fact, the machine was so little known in the wool trade, that the author had never even seen one when the first edition of this book appeared in 1904, and at that date

it was far from easy to obtain data with regard to its action in the combing of wool.

In regard to this comb one thing must never be forgotten: it is based entirely on the nip principle. The nip is an absolutely essential part of the machine, for it alone holds the tuft whilst the pins of the porcupine comb all the noil out of it. It was the patent which covered this mechanism that Mr. Lister was obliged to buy before he could make or sell his own comb in England, and if for no other reason, this circumstance would entitle it to a place of unique importance in the history of wool combing.

The necessity for a nip in all combs but the Noble brings us to a point on which great stress must be laid. It is the difference between combing one's hair and combing every other kind of textile fibre that has once been detached from the skin on which it originally grew. In the first place, each fibre is separately fastened to the skin by its extreme end, and the teeth of a comb can therefore be inserted between the root end of the various hairs and drawn forward to the extreme tip, thereby separating them one from the other throughout their entire length. But it is quite otherwise with wool. There (excepting in the Noble Comb) the fibres must be held somewhere between their two ends; first one end must be combed and then the other, and even then the place at which they are held will be left uncombed and tangled, unless the point of holding be moved, by some means, between the two operations. Therefore, in the Heilmann Comb, after the front fibres are combed, just as the drawing-off rollers take hold of the tuft, an intersecting comb descends between them and the nip. Through it are drawn all the fibres previously held by the nip, and consequently, at two operations, all of the fibres are combed from one of their extremities to the other.

The Heilmann Comb, therefore, differs entirely in appearance and in structure from all other combing

machines. It has no comb as the term is understood to-day—that is to say, it has no circular rows of steel pins set vertical in a large brass circle which revolves in a horizontal plane. The extraction of noil is effected entirely by a rotating cylinder or porcupine which carries from 15 to 18 rows of pins inclined forward in the direction of its rotation.

Before any other combing is done, this porcupine cleans and straightens the fibres forming the front end of the sliver whilst they are held in the nip. When the nip opens, the remaining portion of the staple is combed, as the drawing-off rollers pull the fibres through the intersecting comb and the pins of the nip bed. The actual combing processes are, therefore, really only two in number, and excepting the Noble, the Heilmann is really the simplest of all combs in its actual combing arrangements. But to attain this end it comprises more movements of the most complicated nature than any other machine in the textile trade.

When it is in operation it looks as if every part were moving; and as some of the sections have no less than three entirely different movements superimposed on one another, it is naturally a very difficult machine to understand.

The various parts and movements are as follows:

1. The feed-rollers F supply sliver to the pin bed.
2. The pin bed B opens and shuts.
3. The pin bed moves backward and forward.
4. The pin bed rises and falls with the nip.
5. The nip N rises and falls with the pin bed.
6. The nip bed opens and shuts.
7. The intersecting comb I moves up and down.
8. The plate moves to meet the intersecting comb.
9. The porcupine P continuously revolves.
10. The two sabres rise and fall.
11. The drawing-off rollers R move up to the nip.
12. The drawing-off rollers revolve.
13. The drawing-off rollers reverse.
14. The drawing-off rollers stand still.

As a matter of fact, standing still cannot by any stretch of the imagination be called a motion, but it is no less a fact that the mechanism that controls the rollers has to be much more complicated in order that the rollers may remain stationary for a definite percentage of each stroke they make. For this reason it is fair at least to say that apart from the noil brushes there are fourteen separate controls necessary in every Heilmann Comb, and (excepting one) every one of them is intermittent. Even the rotation of the porcupine, which certainly is continuous, is not a steady motion. During each revolution its speed is altered, and its steadiness is therefore more apparent than real.

In 1907 the Société Alsacienne-de-Constructions Mechanique of Belfort and Mulhouse, who make the Heilmann Comb in France, issued a pamphlet of instructions to users of their machine which was beautifully illustrated by line drawings, and anyone conversant with the actual machine could obtain from them all necessary information; but for the student, or any person who knows nothing of the machine, it is necessary that all the various parts should be shown in their various positions before he can appreciate the intricate and accurate adjustments that result in the excellent work turned out by this complicated little comb. The following figures have, therefore, been prepared to show all the important parts in their various positions. Roughly speaking, they are drawn to scale, but it does not even follow that the scale is accurate, and they must be regarded only as illustrations of the various important parts, and of their differing relations to one another.

Like almost all other textile machines, the wool is fed to the Heilmann Comb through a pair of feed-rollers. Even these rollers do not move at a uniform speed. They are driven by means of a ratchet wheel and a picking mechanism, and they therefore resemble almost

all other motions in the comb in being more or less intermittent. The number of slivers supplied to them is very large, and the whole mass travels forward slowly to the pin bed. This section of the machine differs from anything else in the textile trade, and it may be best described as a series of stationary fallers. The pins are fixed in the upper brass plate pointing downwards, as

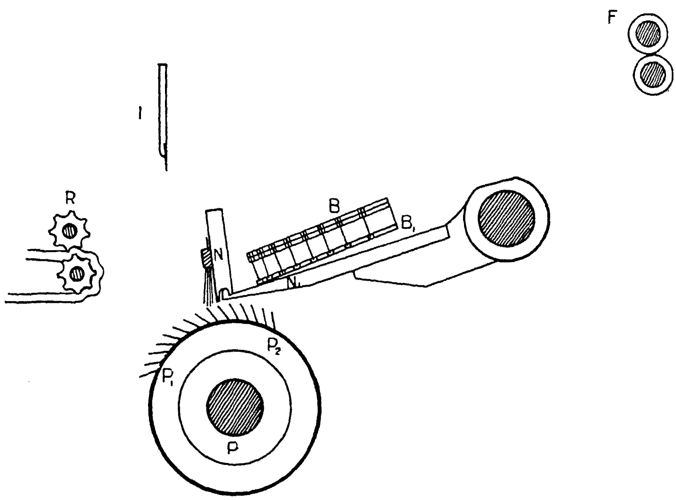

FIG. 70.—THE POSITION OF THE PIN BED AND THE NIP WHEN BOTH ARE CLOSED AND BOTH AT THEIR LOWEST POSITION.

The pins of the porcupine are actually passing through the tuft which projects from the nip underneath the bristles of the brush. The rollers are standing still at their greatest distance from the nip, and the intersecting comb is at its highest point.

shown in the illustrations. They usually consist of eight rows, of which the back ones are coarser and set further apart than those nearest to the nip. Its movements, as already stated, are very complicated, for it not only moves up and down with the lower nip (N_1), but it also opens and shuts and moves both backwards and forwards. After a tuft has been drawn through the intersecting comb and the nip is once more closed,

the upper portion of the pin bed rises till the points of the pins are clear of the sliver, when it moves back towards the feed-rollers. The pins then descend with their points inserted in the holes shown in the lower pin bed plate (B_1) in such a way that all the wool is inter-

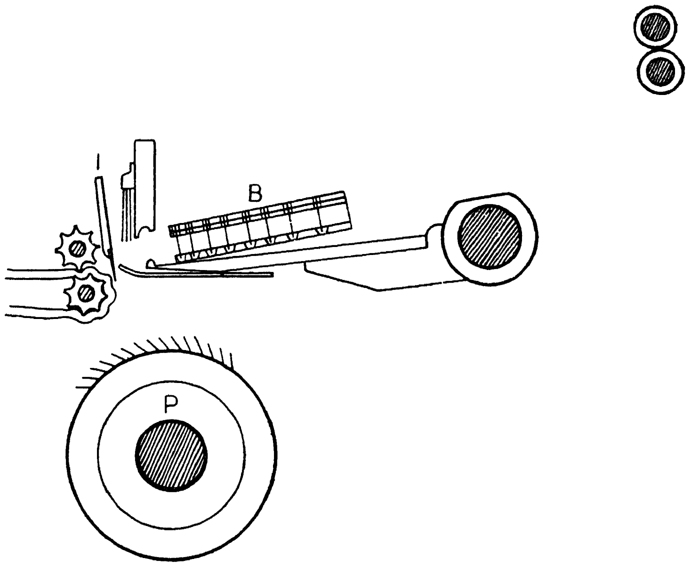

FIG. 71.—THE VARIOUS PARTS OF THE COMB WHEN DRAFTING IS TAKING PLACE.

The nip is open, the pin bed closed, and the intersecting comb is right down through the tuft. It is prevented from escaping by the plate which is moved forward. The rollers are at their nearest point to the nip, and are just beginning to revolve, so that they will draw every fibre which reaches them through the intersecting comb and also through the pins of the pin bed.

sected by the eight rows of pins which now again move forward towards the nip, bringing with them more wool to be treated by the pins of the revolving porcupine.

The various parts of the machine are now in the position shown in Fig. 71, the tuft projecting through the nip in such a way that every pin of the porcupine must go through it as the porcupine revolves. It is

natural to think that some of the fibres would be blown upward by the draught of the revolving cylinder and so escape from the effects of the pins, but all fibres are prevented from so doing by the brush which is placed outside the upper jaw of the nip. Held as they are in this position, it is quite clear that every atom of noil existing in the tuft of wool must be combed out by the pins of the porcupine which revolve rapidly through them.

It has been pointed out in other chapters of this book how necessary it is that combing must begin gently, and only be increased in intensity as the fibres become straighter and more free from noil. Various arrangements are adopted in various combs in order to insure that this shall always be the case. In the Heilmann, an examination of the porcupine itself will show that the front rows of pins at P1 stand much further apart and are much longer and stronger than those at P2. If there are eighteen rows of pins in all, the first rows at P1 will probably only contain twenty pins per inch, but they may be nearly half an inch in length, the last rows at P2 having no fewer than sixty-six very much shorter pins in the same space. This is, of course, equivalent to combing one's own hair first with a very coarse comb before commencing to do so with one which has the finest possible teeth. Such arrangement must help to preserve the length of the fibres which are being treated, and it has doubtless much to do with the efficiency of this wonderful little machine.

As soon as the tuft is combed, almost every part of the machine changes its relation to every other. The nip, the brush, and the pin bed all rise together to a considerable distance above the porcupine, carrying with them the tuft of combed fibres projecting from the nip below the brush. The rollers are then moved from the position in which they are shown in Fig. 70 to

the position shown in Figs. 71 and 72. The intersecting comb (I), which has a very large number of fine teeth —about sixty to the inch—descends to the position shown in Fig. 71, and a curious plate moves forward below the nip in such a way as to prevent any fibres escaping from the intersecting comb. All the important

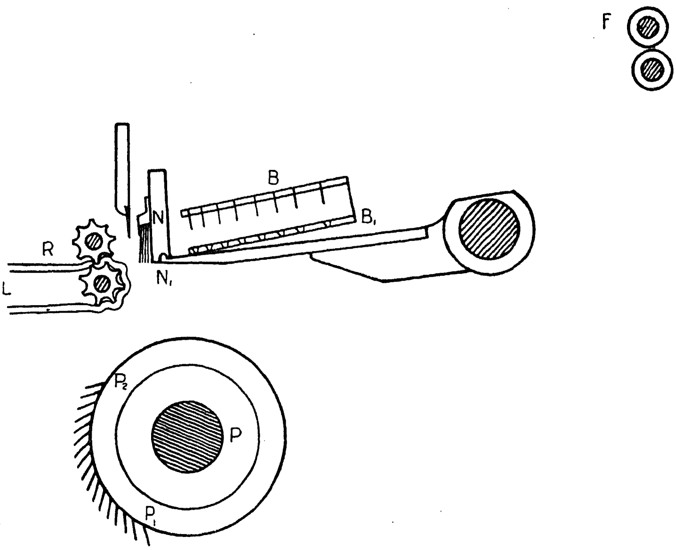

FIG. 72.—THE POSITION WHEN THE PINS OF THE PORCUPINE HAVE JUST BEEN DRAWN THROUGH THE TUFT OF WOOL, AND ARE BEING BRUSHED BY THE CIRCULAR BRUSH TO TAKE OUT THE SHORT FIBRES WHICH, IN THIS COMB, FORM THE NOIL.

The intersecting comb is shown just dropping into position, that the ends of the long fibres may be combed through it. The nip is just on the point of opening.

parts are now in very close proximity to one another, the tuft of wool projecting from the pins of the pin bed through the intersecting comb into the nip of the rollers (R). These rollers at once begin to revolve, and continue to do so until they have drawn all fibres which reach them clean through the pins of the intersecting comb, as well as those of the pin plate.

With this movement, the first cycle of combing is really complete, but the rollers continue to revolve until they have not only drawn the wool clean through the intersecting comb, but have carried it also a few inches along the leather (L). To anyone who is watching the action of this machine, this affords a most curious spectacle. The sliver is entirely broken every time the rollers draw the wool, and it is for this reason that the direction of their rotation has to be reversed in order that the next tuft of wool which is drawn through the nip shall be laid with its points overlapping the tail of the draw which went before it. Nothing can show the wonderful accuracy of the adjustment better than the fact that a sliver may be examined without its being possible for anyone to detect where one draw ended and the next began. Like all other parts of the machine, the action of the rollers is frightfully complex. In order that the extreme tips of every fibre shall be drawn right through the intersecting comb, it is necessary that they should revolve further than otherwise would be necessary. It is this which carries the fibres along the leather, and the mere fact that they are thus carried makes it necessary for the rollers to reverse the direction of their revolution in order that the extreme ends of each of them shall again appear between the upper roller and the leather exactly at the time when it again takes hold of the wool which is to form the next section of the sliver.

It will be seen that the rollers themselves are very small indeed. This is necessary on account of the fact that the Heilmann Comb is capable of dealing with wool of very short staple; and in order that the nip between the rollers may approach as near as possible to the intersecting comb, their diameter is reduced to one and a half inches or even less.

It is not hard to see that the pins of the porcupine

will now be full of noil which has been combed out of the wool, unless some means is taken to keep it clear. For this purpose a brush exists below the porcupine, which revolves at a high speed, its bristles moving in the direction in which the pins point when they are at the bottom. By this means the pins of the porcupine are always free from the short wool which they have extracted, and this wool is brushed away and thrown into tins. It differs entirely in its appearance from the noil produced by all combs which have a circular row of pins, but it is nevertheless true noil, and it is the only form of waste which is made by the machine. There are no backings such as occur in some other types of comb.

The Heilmann Comb has, therefore, several advantages. In the first place, it will deal more efficiently with short material than any other type of comb. It is its capacity to do this which gives it its special value in this country in competition with combs which have so long been regarded as a necessity to the trade.

In spite of its ability to deal in a satisfactory way with short wool, it must be remembered that when it is doing such material the output is very meagre. In this respect, the Heilmann resembles all other combing machines. The output may not be in exact proportion to the length of material, but nevertheless a comb invariably turns out less of short material than it does of long, and the Heilmann is no exception to the general rule that, from a commission comber's point of view, short wools are always undesirable.

CHAPTER XII

FINISHING

Wool is gilled after combing for several reasons—

1. To blend all long and short fibres uniformly through the sliver.
2. To straighten the fibres, and make all of them as nearly parallel as possible.
3. To apply exactly so much water, that the proportion of wool to water is always standard and uniform.
4. To make every yard of any lot exactly the same weight as every other yard of the same lot.
5. To build the sliver into a ball which will easily unwind, and can be carried in the least possible space, without having the extra weight of any bobbin or support.

It is one essential of a perfect sliver that long and short fibres should be blended uniformly throughout every portion of it, if the best results are to be obtained in spinning; and, as no combing-machine delivers the fibres equally distributed throughout the sliver, two fine gill-boxes are always used to mix the different lengths of fibre thoroughly. As was shown in Chapters VII. and VIII., the hen-wing sliver from the horizontal drawing-off rollers of the holden and Lister combs has all the short wool on one side and all the long wool on the other, as it lies on the leather, and when rolled up the long fibres are all in the middle and the short ones on the outside. As the wool comes from the Noble comb the fibres are better blended, but they

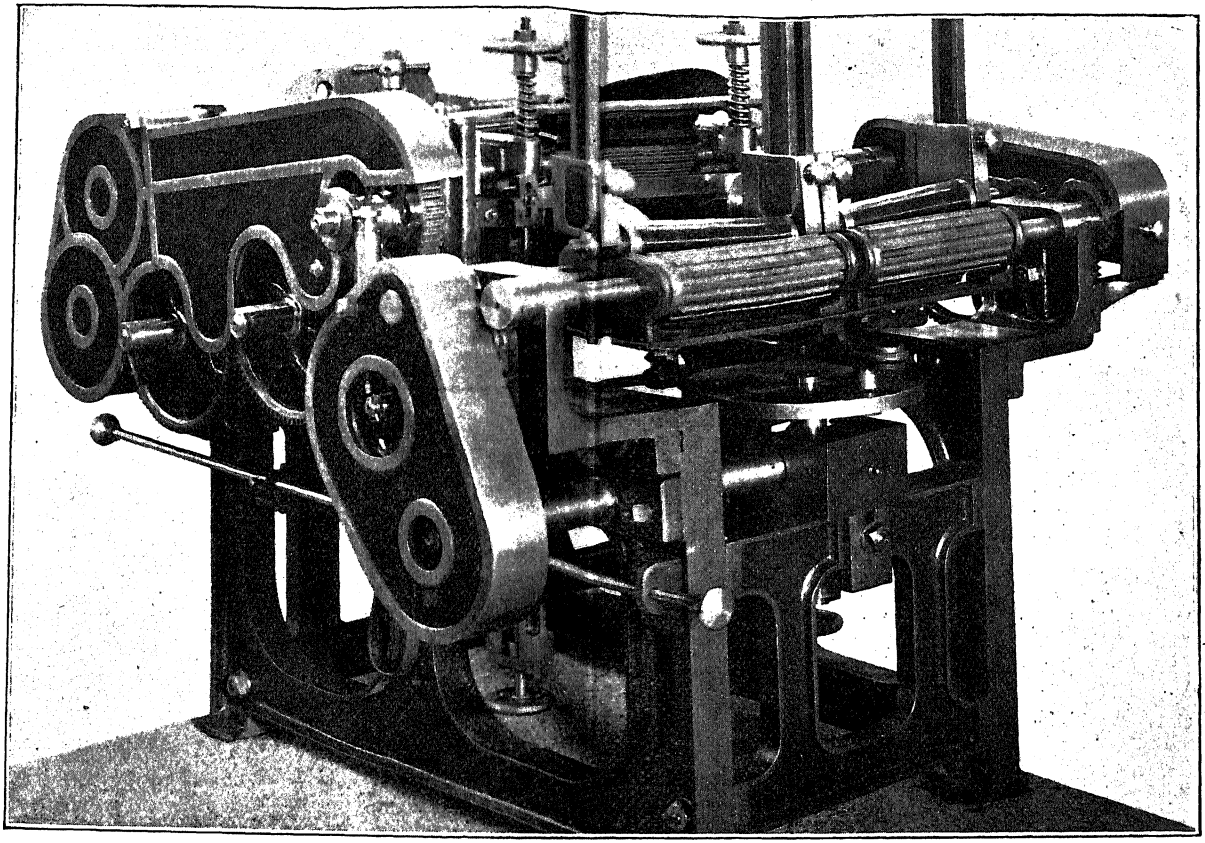

Fig. 73.—Finishing Gill Box, with double balling head, by Prince, Smith and Sons

To face page 194

are in the form of four small slivers lightly twisted together running into the one can, the fibres of the two which come from the small circles being shorter on the average than the fibre from the large circle. The two finishing processes blend all these fibres uniformly and produce a top which is straighter and smoother than the wool in any preceding process.

As a rule the first gill-box delivers the wool into a can. The fallers are three per inch in double thread screws for Botany, or half-inch fallers for crossbreds. In both cases they would be pinned over 10 inches, with two rows in each faller of sixteen pins per inch and fifteen pins per inch respectively.

It is perhaps more important that the wool should be put into cans for the finishing-boxes than for any other process of combing, because a lot of balls, even of finished tops, require no small amount of attention to make them run up without any ragged or turned back edges; and it must always be remembered that if a sliver is torn at the edge, so that any of the fibres, which should be pointing forward, trail and form a loop, there must infallibly be a loop also in the top, and every loop there means a slub in the yarn.

After they leave the comb the slivers from twenty-eight cans are run up to the back rollers of the first finishing-box. If each sliver weighs $1\frac{1}{4}$ ounces for 10 yards, and if there be a draft of five on the box, the resulting sliver in the can is very thick, say, 7 ounces for 10 yards. The sliver is made thick, because it will then run more easily from the can, and is less likely to fray at the edges. Moreover, only three such slivers need go up to each side of the last box, and there is therefore so much less opportunity for ends to break down. A good hand may be able to piece a sliver without making any lump or visible unevenness in the top, but in practice a great many of the faults which

are found in tops are due to faults in the finishing-boxes; and, as has been already stated, these faults are always serious, because they cannot be remedied in a later process. The three slivers, each of 7 ounces for 10 yards, are drafted again five to one in the final box, and the result is naturally a finished sliver or top weighing $4\frac{1}{5}$ ounces for 10 yards. In crossbreds the weights would be proportionately heavier in both boxes, but as the slivers from the comb would also be thicker, the number of ends up in each process would not differ very much. To get regularity of weight in the yarn the spinner must have all his tops of exactly uniform length per ounce, and he must also know exactly what is the weight of 10 yards in every different quality.

The standard weights generally given are—

Botany, 4 to 5 ounces for 10 yards;
Crossbred, 6 to 7 ounces for 10 yards;
Long wool, 8 to 9 ounces for 10 yards.

The weight of wool in every yard of sliver is, of course, affected by the amount of oil and water which it contains, and it is therefore necessary that the quantities of both of them should be accurately ascertained. We saw how the oil supply was regulated in the chapter on backwashing, and it is unfortunate that water cannot be applied by the same volumetric methods. Unfortunately, water evaporates rapidly in passing through the heated combs, and in every process where the fibre is exposed, as open sliver, to the warm dry air of the combing shed: it is to make up for this loss that water must be added to the sliver at the last box before the wool is made up into ball. Water is almost always applied after the wool leaves the front rollers of the first finishing-box, so that it may be well mixed into the wool by the fallers of the last box. The slight draft of the calender rollers keeps the sliver fairly tight, and in this way it is pulled across the face of a brass roller,

which revolves very slowly in a trough containing water. The water is always maintained at a uniform level, and the amount applied is regulated by altering the speed at which the conditioning roller revolves. If the roller were to go quickly it would lift a very large quantity of water, and the broad dry sliver would absorb as much as 30 per cent. of its own weight. When the roller revolves slowly, the bulk of the water has time to run back down the roller surface before it reaches the point where the sliver touches the roller. There, there should be just sufficient water to make the top so damp that it is in standard condition—that is to say, the ball must contain not less than $81\frac{2}{3}$ per cent. of pure wool, not more than $2\frac{1}{3}$ per cent. of oil, and exactly 16 per cent. of water. The water is always uniform, except in the case of tops combed without oil. The oil and wool together must therefore always be equal to 84 per cent. (See Chapter XIII.)

The balling head has already been referred to several times, but in no other process is it as important as in finishing that the balls should be perfectly built. A description of the requisite motions and their results has therefore been reserved for this place. We will take the case of a Botany finishing-box. (Figs. 73 and 74.) The sliver goes straight from the front fluted rollers A to the rollers BB, all of them moving with the same surface traverse. The roller C rests on the rollers BB, and is capable of rising vertically while still remaining parallel with BB.

When all the rollers are in motion the sliver is wound round C, and as the number of layers of wool increases it is clear that C must rise until the desired size of ball has been made. A ball made in this way, without any traverse motion, would be so very narrow that it would at once fall to pieces; but supposing that it could ever be built up, it would have every succeeding wrap

parallel with the one before it, and this in itself would be a serious drawback. To build a ball by machinery, two motions are necessary: there must be the rotary motion to wrap the sliver round the spindle and a transverse motion to move the sliver backwards and forwards. To make this possible the relative positions of A and B must be continually altering; but clearly the position at which the sliver leaves the front roller A cannot be made movable, and if a traversing conductor were put in between the front rollers and stationary balling-rollers B, the tension on the end would always

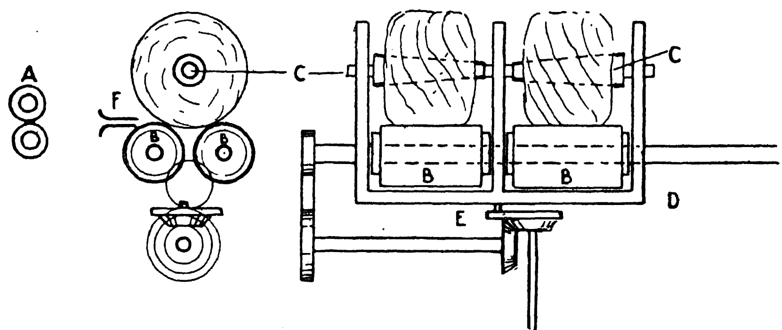

FIG. 74.

be altering so seriously as to affect the size of the sliver. There is therefore only one way out of the difficulty. The balling-rollers BB must not only rotate, but they must at the same time move backwards and forwards about 6 inches across the end of the funnel or conductor F, which guides the sliver to the rollers.

The two horizontal shafts which carry the rollers always rotate at a definite speed and they have deep keyways along their entire length. The rollers BB are so arranged that they can slide freely along the shafts when moved by the frame D, which is itself made to traverse by the bevel wheels and the crank pin E. The rollers also carry keys which slide in the keyways

and cause the rollers to rotate at exactly the same speed as the shafts. This gives exactly the same result as if the funnel with the sliver were traversing, and the rollers were revolving without any other motion.

The relative surface speed of the rollers B and the number of traverses which they make per minute is very important. If the traverse motion should move backwards and forwards in exactly the same time that it takes the rollers to pay out one wrap round the ball, it is clear that many succeeding wraps will be exactly side by side and that the ball will be thrown somewhat out of shape. In every ball the first wrap round the bobbin is only 7 inches in length, whilst the outer wraps are 37 inches, and if a suitable traverse were fixed for the 7-inch wrap it would be much too fast for the 37-inch. In practice the traverse is nearly always made uniform, to suit an average wrap of about 22 inches, giving three wraps for every traverse in the centre of the ball, and three-quarters of a wrap for one traverse on the outside. This means that when the ball is unwound one place will always be found where the slivers never cross one another, every wrap lying parallel with the one preceding it, and it is at this place that there is the greatest difficulty in getting the sliver to unwind without the edges adhering to other fibres on the ball, and making ragged edges as a result.

A more perfect ball may be built with a traverse which varies as the ball increases in size, being so arranged that there would be three wraps to every traverse at the centre of the ball, with the rate of traverse decreasing so that at the outside there is less than one traverse to every wrap. The usual friction-roller working on a table gives very good results in thus reducing the speed, but the necessity for setting such a motion every time a ball is doffed makes it rather

troublesome to use, and it has not yet found general favour in the trade.

Measuring.—When the balls come from the last gill-box it is essential that they should all be uniform in weight, and therefore contain the same length of sliver. We have already considered the question as to the drafts and number of ends necessary at each box to make a Botany sliver of 4 ounces for 10 yards, and it only remains to make the box stop automatically when the rollers have delivered the length required for

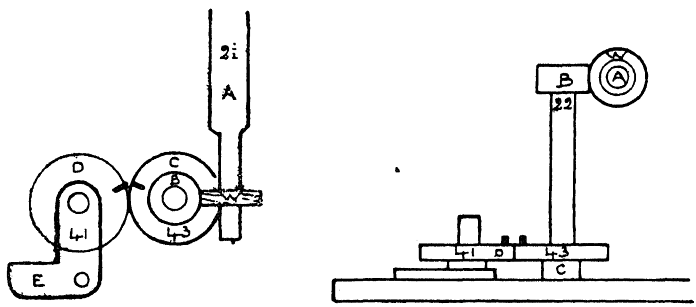

FIG. 75.

one ball. The motion used for this purpose is known as a knocker-off, the type shown in Fig. 75 being in most general use.

A five-pound ball of four-ounce sliver will contain $\frac{5 \times 16}{1} \times \frac{10}{4}$ or 200 yards, and the wheels must be arranged to give this length.

The wheel C is usually made with an indivisible number of teeth; 71, 59, 61, and 43 being common sizes. The wheels C and D both have one tooth projecting beyond the others. If these two long teeth start at the same time, from the point exactly between the centres of the two wheels (which is naturally the only place where they can meet), each wheel must

move a number of teeth equal to the least common multiple of the teeth in the two wheels, before the projections can meet again. 1763 is the least common multiple of 41 and 43, and in that number of teeth the wheel C will have revolved 41 times—that is to say, the wheel C will revolve as many times as there are teeth in D, and the output of the front roller before the projections meet will be the circumference of the roller A $\times$ the teeth in the worm wheel B $\times$ the teeth in D, or $8 \times 22 \times 41 = 7216$ inches, or 200 yards 16 inches. When the two teeth meet they force the wheel D and its studplate E away from C, and this movement stops the box.

CHAPTER XIII

TOPS AND TOP TESTING

In dealing with tops after they leave the finishing-box there are a number of standard terms used, which unfortunately do not always carry exactly the same meaning, and in this chapter "quality" is taken to mean diameter or fineness of fibre, although its use in this sense may lead to some slightly anomalous phrases. Length is a term which is solely relative, for it must be clear to anyone who has seen a 64^s and a 40^s top side by side, that what would be excessive length in the Botany would be so short as to be entirely useless in the crossbred.

Quality.—All tops are classed under quality numbers, which are supposed to represent the counts to which they will spin; but in order to spin to any desired counts, a top must possess a certain length as well as the requisite quality. Originally a 60^s top was understood to be one which had sufficient length as well as sufficient quality to spin to 60^s counts; but it was also well known that if a top were below a certain quality no amount of length would make it spin, and hence it happened in the course of time that the quality or diameter of fibre below which no top could be spun to 60^s came to be recognised as a 60^s quality whether it had sufficient length to spin 60^s counts or not.

As a matter of fact, many so-called 60^s tops will not spin to 50^s, for though they have the quality, they have not the requisite average length; and some tops which

are known as short 60^s have few if any fibres in them which are equal in length to the average which is necessary in order to spin a good 60^s, and they can only be used for thick weft yarns up to about 30^s counts.

Through this course of events it has come about that 60^s is an arbitrary term for a recognised diameter of fibre; and now for almost all qualities there is a certain fineness of hair which is accepted as the standard for that quality, although it may be impossible to spin the top to counts equal to the number under which it is sold.

In woollen yarns we have seen that the individual fibres are allowed and even helped to curl and contract as much as possible, the waviness of the fibre in the

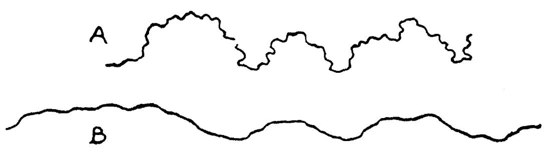

FIG. 76.

grease being exaggerated by the nature of the processes, to such an extent, that any single fibre may not extend for more than half its own length along a thread, but may lie in a position analogous to Fig. 76, A.

In fine worsted spinning it is exactly the contrary, and if it be clearly understood that quality without equivalent length is absolutely useless for spinning fine Botany yarns, it explains the necessity for a comber to obtain the greatest possible length of top from every lot he combs, because every additional quarter-inch of average length adds to the spinning power and value of the top and to the proportionate price which the topmaker will get from the spinner. As the fibres come from a worsted card they lie much as they do in a woollen sliver, but each succeeding worsted process tends to stretch and straighten them to such an extent,

that a wool which could only be stapled to an average length of $2\frac{1}{2}$ inches in the grease will look about the same length in the carding, but it may appear fully $3\frac{1}{2}$ inches long as it comes from the final gill-box.

It is easy to see that this straight position is not natural to the fibre, for if a staple (or draw as it is called when taken from a sliver) be taken from the new top and laid upon a blackboard, it will soon contract visibly in length. If tops are taken fresh from the comb to the spinning, this tendency to contract is very detrimental. In the same way, if a combed sliver be run loosely into a can, the same shrinkage and curling go on, till the top begins to look short and fuzzy; but when it is wound tightly on to a ball each fibre, though retaining some of its natural wave, is held approximately straight, and if left for some days in that position it will lose all tendency to contract to its former shape, and each fibre will resemble Fig. 76, B. A top in this condition invariably looks finer than one of equal quality in which the fibres are curly; in fact, it may be said that the quality appears to vary directly in proportion as the hairs are straight or very wavy.

Unfortunately, makers are often compelled to submit samples from lots which are quite new, although it is a disadvantage both to themselves and their customers to do so; for if a spinner be using an old lot of a certain standard quality, and a quite new sample of the same quality is submitted from a newly combed lot, it would be impossible for them to look alike, even if they were different combings from the same pile of wool. Tops should always be allowed to lie before they are judged or used, for they improve very rapidly in the first few days, and in appearance and spinning power they are seldom at their very best until they are three weeks old.

As it is impossible always to leave two tops for comparison until the newest of them has lain long

enough to set naturally, a careful judge will use other means, as far as possible, to equalise their appearance rapidly, and this is best done by pressing the new top severely for as long as possible. If a top 12 inches in diameter and 6 inches thick be laid on its side and pressed until it is only 4 inches thick it will naturally increase in diameter, and if such increase be only 1 inch it is obvious that the length of each of the exterior wraps of sliver must have been extended 1 inch in every 12 inches; and if it remain in that position for a few hours the heavy pressure will cause the fibres to set sufficiently to give the buyer a fair chance to estimate its quality approximately.

This pressing is best done in a simple screw press, in which one or more balls can be placed, one above the other, separated by boards; or the top may be placed between two boards of suitable width, with sufficient weights on the upper one to give the required pressure.

When comparing tops it is always best to take the sliver from the outside of the ball and not from the centre, for it is obvious that when the bobbin, on which the top is built, is pulled out, the inner layers of sliver must contract to fill up the hole. All pressure will thus be removed from the first few yards near the centre: they seldom appear alike in any two balls, and they always look more curly than the straight sliver on the outside of the ball, where it is always kept at the same tension at which it was wound by the gill-box, so that, in the course of three weeks, the fibre will set permanently in the position in which it is held. It is true that the extreme outside layers are apt to dry and become somewhat fuzzy with being handled, however slightly; but if these few yards of sliver are removed, the underlying layers will be found to be straight and smooth, pressed by the outer layers into the very best condition for comparison.

In the old days, when the spinner nearly always bought his own wool and knew exactly what each lot of tops contained, it was not necessary to spend so much time and care on the examination of each lot of tops, because lots of wool which are equal in quality and length must give equally good results in the top unless the fibre has been damaged in any way by careless treatment in the process of combing. But when tops are made by one man and spun by another it is only under special circumstances that the spinner is told what classes of wool they contain; unless he cares to pay something rather above the market price for a top, guaranteed, for instance, to contain nothing but Port Philip greasy wool. In ordinary transactions the seller will give a general idea as to what his tops are made from, and may guarantee that they do not contain any class of wool which the buyer knows will spoil the finish of the goods for which they are required; but the very large majority of tops which are sold in the open market are sold simply on their merits, and a spinner who buys them must be able to judge whether they will suit his purpose or not, without knowing from what class of wool they are made. For certain trades this is recognised as impossible; for up to the present there is no means of ascertaining by any examination, however careful, what class of wool a top contains. For example, if three tops of equal quality and length were made from super Port Philip, super Sydney, and super New Zealand, it is very doubtful if any judge could tell them apart; and if they were blended it would be utterly impossible to form any idea of the proportions, although they would certainly not finish equally well, if woven into some classes of cloth. On the other hand, it is now generally known that superior qualities of Italian cloths can only be made perfect when the right class of wool is used, and, as a

consequence, the trade in superior Italian yarns is almost entirely in the hands of spinners who sort their own wool and make their own tops. There are, however, a few exceptions to this rule, for amongst the first-class topmakers there are some who use such uniformly good wool, that they are not afraid to show their customers the wool in the bale, the matching, and the pile, and who deal on such a large scale that they will take orders and guarantee the delivery of tops from any class of material, be it New Zealand scoured or Port Philip greasy. The advantages of such a straightforward system of trading to both buyer and seller are alike obvious; and it is greatly to be hoped, in the interest of the trade, that these firms will reap such a reward, that self-interest will prompt others to follow their example.

Length.—We have now seen that for some special purposes it is necessary that the spinner should know exactly from what class of wool his tops are made, but that the great majority of tops are bought and sold simply for what they are worth, as judged by their appearance, and it is therefore very important for everyone to be able to judge accurately of the spinning qualities and value of all tops with which no guarantee is given.

If a sliver of top be drawn asunder and a single draw be drawn from either end, in the finger and thumb, there are two features which can easily be judged—(1) the fineness or diameter of the fibres; (2) length of the longest hairs.

In regard to quality, we have also seen that a certain fineness of fibre is absolutely necessary for the spinning of certain counts, and that, therefore, there is an arbitrary but definite standard which must be attained by every top destined for a definite purpose; and if

standard samples are kept for reference, it is easy to lay the new top side by side with the standard and ascertain by comparison if the one offered for sale is good enough for the buyer's purpose. Ability to judge of the quality quickly and with accuracy naturally requires much experience, but when the experience is once acquired the process is one of extreme simplicity. But to judge accurately of the average length of a top requires much more time and care.

As a matter of fact, the length of the longest hairs is of very little moment. It is the average and pro-

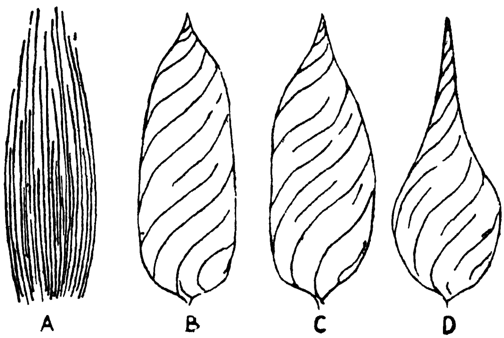

FIG. 77.

portionate length of all the fibres in the sliver which is of importance to the spinner; and unless he is in a position to judge of these things, he can never be certain as to how the top will spin. The simplest way of judging is to break a sliver carefully, and holding one end of it in the left hand, with about 4 inches projecting, take firm hold of the extreme tip with the right finger and thumb and draw away a bunch of fibres. If this is carefully done the bunch will contain fibres of all the different lengths composing the sliver, and if the two ends of this bunch are now twisted in opposite directions, it will assume a shape varying according to the proportion of long and short wool it contains.

When drawn from the sliver before they were twisted the fibres would lie as in Fig. 77, A. If the average length of the fibres be very uniform, when released from the fingers it will take the shape of Fig. 77, B. Most tops would give a figure much more like C; and D would represent tops containing such a large proportion of short wool that they would only spin very poorly. Unfortunately, no *accurate* idea can be formed of the average or proportionate length of the various fibres by this method. To make an analysis a blackboard is necessary, the most convenient shape for Botany tops being 2 feet long and 6 inches wide, with a curved face, covered with black velvet. For crossbreds the board must be so much wider that the extreme length of the longest fibres will not quite reach across it: it should be provided with ribs or feet to keep it from the table, so that the fingers can easily grip the edge when holding the sliver in position. (See Fig. 78.)

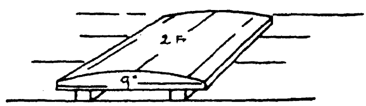

FIG. 78.

Analysis.—To make a correct diagram from any top it is, of course, necessary to get a bunch of fibres which contains the same proportion of long, medium, and short fibres as does the top. To do this, a sliver must be taken in two hands, and held at two places about the same distance apart as the length of the longest fibres in the top. It must then be drawn carefully apart, so that no fibres are broken, and from the end which is to be used all the loose fibres must be picked out, until the sliver has a comparatively square end, with all the fibres ending as nearly as possible at one point. A single staple must then be drawn carefully from the sliver which has been thus prepared, and with it held tightly in the right finger and thumb,

it must be laid upon the velvet board in such a way that the tips of the longest fibres reach to the farther end of the board. These long fibres are then gripped against the board by the thumb of the left hand and the remainder of the sliver drawn away, leaving the few long fibres lying straight across the board. (Fig. 79, A.) The staple must never be removed from the right hand, but again laid on the board just beside the long fibres, with the tips of the longest remaining fibres again on the far edge, where they must again be gripped against the board and the remainder of the staple withdrawn, leaving the two sections side by side (B),

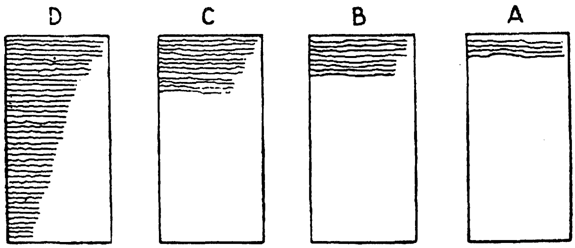

FIG. 79.

the second one being necessarily shorter than the first. The process must now be repeated a third time (C), and so on, until there are no fibres left in the right hand. The result will be a figure in which all the fibres have one end on the left edge of the velvet, and their other ends at gradually decreasing distances from it (D), so that the relative proportion of long, medium, and short fibre can be not only seen, but measured, and the relative spinning value of the top ascertained.

Theoretically, the best top for spinning would be one in which all the fibres were of equal length; but this can never be obtained in practice, and the best tops are those in which the length of all the fibres is most nearly uniform. Amongst the super Port Philip 60s and 64s, lots may occasionally be found which vary

very little indeed, and give a diagram with few fibres less than half the length of the longest. (See Fig. 80, A.) But such tops are very rare indeed, and few can be found containing less than 30% of fibres which are less than half the length of the longest. (Fig. 80, B.)

In the cheapest tops it is not unusual to find the shape of the figure reversed (Fig. 80, C) with comparatively few long hairs, a considerable proportion of medium, and a long tail of short fibres, which spoil the spinning power of the top, and only serve to fill up the thread and make a thick yarn of low tensile strength, in which the few long hairs help to hold the whole together.

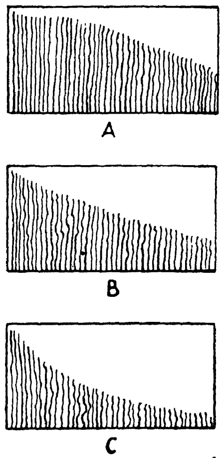

Fig. 80.

When the fibres are spread evenly upon the board in diagram form, it is of course possible to judge very accurately of quality as well as length, and in some cases this method of judging quality is of great use. It is very unusual for fine and low fibres to be equal in length, the low ones being generally the longer. In these days, when it is not unusual for a top to contain more than one quality of wool, this method of analysis is doubly valuable, for when the intermixed fibres are lying close together in a bunch, as in a single draw, the differences of quality are not discernible, and the average quality appears to be halfway between the fineness of the finest and the thickest fibres; but when a diagram is made from such a blend the short end of the figure is finer in quality than the longer end, and though it is impossible to analyse the quality as accurately as it is to analyse the length, it is clearly better than judging quality from a single draw.

We will suppose, for instance, that a lot of wool intended for 60s top proves to be of good length but low in quality (say it averages 58s), and hence it is visibly unfit to spin to 60s. To remedy the defect, 30 per cent. of fine short 64s is added to the blend. This will give the necessary softness of handle, and the necessary average quality, if it be judged in the sliver only; but there would be a variation in length which would be fatal to the regularity of the yarn, and if such a blend were analysed on a blackboard the qualities and lengths of the two wools would be discernible.

The diagram itself would probably show a double curve as in Fig. 81, and, if divided into three sections, section E would contain only the longer fibres of the 58s quality; section F would contain the shorter fibres of the 58s quality mixed with the longer fibres of the 64s top; and section G would contain nothing but the short fibres of the 64s, which would be finer in diameter than any other portion of the top, and so short as to be positively detrimental to the spinning: in extreme cases it might even cause lumpy or broken sliver in the top itself.

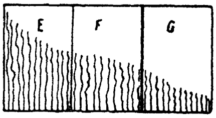

FIG. 81.

The usual standard of ratch for a good uniform quality is to have the back and front rollers a little further from one another than the length of the longest fibre in the sliver. It is clear that if a sliver containing both very long and very short fibres were put through a box set in this way, the long fibres would be nipped and drawn by the front rollers immediately they were freed by the back rollers, and would form an even ribband or thin sliver of long fibres. But with the short fibres it would be quite different; for many of them would be freed from the back rollers before the points of any of them reached the front nip, and as

soon as any of them had travelled so far forward they would all be drawn through, together with all other short fibres which were free from the back nip. This would cause a lump in the sliver, which would then continue to run thin until another series of short fibres had moved forward from the back to the front rollers, when they in turn would go through in a lump to form another inequality in the sliver. The process of making a uniform ribband of long fibres and lumps of short fibres would therefore be going on at the same time, and the result would be a sliver lumpy along its entire length, as represented in diagrammatic form in Fig. 82. As a matter of fact, the short fibres would be distributed transversely amongst the long fibres, but they would all come at certain distances along the sliver

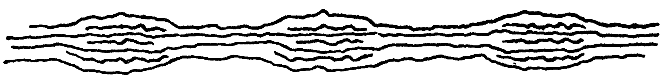

FIG. 82.

and the result would therefore be much the same as if they came between two uniform ribbands.

All practical readers will see the impossibility of explaining in print all the utility of blackboard testing, and although many of the advantages must be apparent to every reader, it is only after long use and practice in analysing that a buyer comes to judge of all the properties of the tops he is testing; valuing them not alone by their length and quality, but also by the freedom or difficulty with which they draw, and the manner in which the fibres hold to or slip on one another.

Spinning Power.—For the comparison of consecutive lots of tops following one another as the same quality this system of examination is almost infallible: but every rule has an exception, and about three years ago almost

all the crossbred spinners found this to their cost, for though their 40s tops were of exactly the same length and quality as they had been for years, the spin throughout the trade became so bad that many spinners were obliged to add such a proportion of more expensive tops to their qualities in order to make them spin decently, that it robbed them of all profit. The most careful judges failed to find any reason for the falling off until they used a microscope, and then it was found that for some obscure reason, which could only be attributed to climatic variation, the serrations on the fibres and the size of the scales had altered on almost all the Australian crossbred wool, and though the length and quality remained unimpaired, the result was such a reduction of spinning power that wools of much smaller diameter and therefore more expensive were necessary to produce the requisite fineness of thread.

Fortunately, this instance stands almost alone in severity, and in spite of it, it may be said that the standard types seldom alter in the sizes of their scales and the number of their serrations; but it went to show how great a part scales and serrations play in the spinning value of wool. As a rule, it is quite unnecessary for a practical judge of tops to use a microscope in his investigations, but it is well to remember that besides depending on length of hair, fineness of fibre, and suppleness of nature, every top has invisible attributes which fill an important place in its practical value.

Condition.—Hitherto no mention has been made of any property of tops which was not inherent to the raw wool, but no practical man can overlook the great physical changes effected in the fibre by the processes of washing, carding, and combing, and the effect of these changes must be thoroughly considered.

In its raw state, as it comes from the sheep's back, the wool fibre is not only overlaid by a fine layer of natural grease, but it actually contains a certain proportion of the same fat within the fibre itself. It is to this free natural application of a suitable lubricant that wool owes its great suppleness or "nature," and when this grease is too completely removed, the softness of the fibre suffers proportionately.

If washing is properly done, so as to thoroughly cleanse the fibre, the whole of the exterior grease must be removed, but if the heat be too great or the reagents employed be too strong, the yolk within the wool itself is also removed, and the value of the wool greatly reduced.

Wool also absorbs a certain amount of moisture in the washing, but this is almost all evaporated again before it leaves the heated circles of the combs, and it is therefore necessary to add such an amount of oil and water in the various processes as will leave the fibre in the most suitable condition for the special purpose for which the top is destined.

Many elaborate theories have been propounded to fit with the known facts respecting the necessity for working wool in a moist condition, and for the necessity of also adding a given percentage of oil. Everyone knows that if a sliver of top be pulled asunder quickly the two attenuated ends will not lie in smaller compass but will spread or fly in such a way that each end of the broken sliver may be twice the diameter that it was before—*i.e.* the sliver A (Fig. 83) when stretched takes the form B, and when broken should *theoretically* resemble C, but in *practice* it is as shown at D.

This tendency to fly has always been attributed to frictional electricity, produced by the movement of the fibres upon one another in the process where there is

any tendency to fly. It is, however, contrary to all previously accepted theories of frictional electricity, that a bunch of fibres containing 16 per cent. of water and 2 per cent. of oil should be capable of generating a force so strongly repellent.

Even yet it can only be said for certain that a moist warm atmosphere and an excessive addition of oil or water of the top are the surest means of preventing fly. But moisture has always been known to destroy the effects of frictional electricity, and the fact may therefore be taken to show the correctness of recent con-

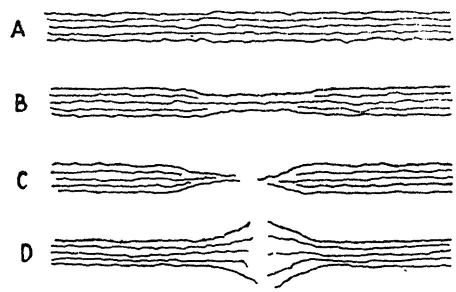

FIG. 83.

clusions. It is also well known that, on dry and frosty mornings, tops in every process, whether in oil or dry, fly much more, in spite of the application of heat and artificial humidity in the atmosphere of the room.

Condition and Cost.—People who make, comb, and spin their own tops can, of course, please themselves as to the amount of oil and water which they put on to them, for though the *cost* of a *top* is largely altered by the addition of *water*, the *cost* of the *yarn* will not vary to any material extent; because any excess of *water* evaporates in drawing and spinning until the normal condition is reached. On the contrary, *oil*, applied in the combing, remains in the wool through

all processes, and reduces both the cost of the top and the cost of the yarn.

In the far more numerous cases where wool is combed to be sold as top, it is clear that the application of more or less water will reduce the price of the top in direct proportion to the amount added; because the water costs nothing. The application of oil is almost equally remunerative; the best olive oil costs less than ninepence per pound, and as each pound weight of it, which is put on to a given weight of Botany top, will be paid for by the purchaser at the price of the top (say, 6s. per lb.), it naturally pays makers to add as much oil as their customers will take.

When tops are combed on commission things are slightly different, as the comber is only paid at rates varying from 6d. to 8d. on every pound of top which he delivers. In respect to water he is in exactly the same position as the maker; it costs nothing, and he is paid the price for combing on every pound of water which he applies to the wool; but in regard to the oil it is now different, for the topmaker expects to have the best olive oil used, and it is the custom of the trade for the comber to supply it gratis. But olive oil costs more per lb. than the 8d. per lb. which is charged for combing average Botany tops, and therefore, by using oil in place of water, the comber actually loses money on every pound of oil he applies; the amount of loss being very small on the lots for which he is paid 8d. for combing, whilst it is 50 per cent. on lots at 6d. It must also be remembered that a proportion of the oil applied in the backwashing is absorbed by the noil, and that the comber is paid only on the top he produces, and nothing for the noil which results from it. This means that he makes a percentage of loss on all the oil which goes on to the top and a dead loss on all that gets on to the noil, and it is therefore to his

interest to use as little oil as will satisfy the topmaker.

In most transactions, therefore, there are three contending interests in regard to condition (as the application of oil and water is called). The spinner (or buyer) of the top wants as little water as possible and just as much oil instead of it, as will make the top spin in the best possible way. It is to the interest of the topmaker (or seller) to have as much both of oil and water as the top will carry, because both reduce the cost of the top. The comber is anxious to put on as much water as the spinner will take, and reduce the quantity of oil as far as the maker will allow, in order that he may be paid for as much weight as possible, and expend no more than is absolutely necessary on the cost of production.

It was a considerable time after the introduction of commission combing before it was possible to fix a standard of condition which would meet the wishes of these three opposite interests, for it is found that different classes of wool require oil in such different quantities, to put them into the best possible condition for working, that any one standard for oil would have been arbitrary and injurious.

The first conditioning-house established in Bradford adopted 6 drams to the pound as the limit of oil for all classes; but for various reasons this had to be abandoned as too hard and fast, and though the amount usually applied now is very near to this figure, sometimes more and sometimes less is used according to agreement or necessity. This makes it desirable that when purchasing any lot of tops the buyer should know how much oil they are supposed to contain; with a stipulation that, if the conditioning-house shows that the amount is exceeded, the seller must concede the equivalent in money.

The fixing of a standard for moisture was quite a

different matter. Wool has a great natural affinity for water, and even wool clothes, which are supposed to be quite dry, contain a very appreciable amount of moisture. It was found that even when tops were combed on circles at the usual heat (about 220° F.), and finished without having any condition applied to them, they were so far from "bone dry" that every pound of top still contained from 1½ oz. to 2 oz. of water. That is to say, that in an ordinary atmosphere tops will never contain less than 10 per cent. of moisture. But it is also well known that tops combed with only this minimum quantity of moisture will never spin in the best possible way until they have been put into a cool, moist atmosphere to set.

It was soon discovered that tops combed without the artificial application of moisture, not only set but increased rapidly in weight when left in a cool, damp place, and they continued to absorb moisture from the air, until they reached the condition in which they were best fitted for spinning. Beyond that point they increased in weight very slowly, if at all, and careful testing showed that nearly all classes of wool have the power to absorb water up to about 19 per cent. of their original weight in a normal cellar, whilst beyond that limit it requires the mechanical application of water, or a very saturated atmosphere to increase their weight further. It is also well known that if tops containing more than 19 per cent. of moisture are placed in the same place where the dry tops are gaining weight, they will begin and continue to lose weight, until they also are very near to the 19 per cent. standard.

We have seen that the point beyond which tops will not absorb any more moisture is the same as that at which they are in the best possible condition for spinning, and that point was wisely adopted as the standard for moisture of all tops in oil. When tops are sold the

buyer therefore expects them to be 16 per cent. condition, and unless he is told to the contrary, he is at liberty to have them tested by a public conditioning-house and to claim from the seller on all water which they contain above the standard.

These figures apply to tops combed in oil, for it is a serious anomaly, that tops which do not contain $2\frac{1}{2}$ per cent. of oil (or thereabouts) are bought and sold on a lower standard of moisture, which is $\frac{3}{4}$ per cent. or $1\frac{1}{2}$ drams per lb. lower than the standard of tops combed in oil. This is contrary to common sense, also to established facts.

If a lot of tops be sent to the conditioning-house to test, the figures returned will be based on a 19 per cent. regain, which is the exact equivalent of the standard loss of 16 per cent. or 2 oz. 9 drams per lb. For instance, if a spinner buys a pack of 240 lbs. of tops containing the standard condition, he will have delivered to him only 201·6 lbs. of dry wool and oil and 38·4 lbs. of water. Regain is calculated on the nett weight or weight of dry wool, which in this case is 201·6 lbs., and 19 per cent. of this is 38·39 lbs., which, if added to 201·6 lbs., brings the weight up to exactly what it was before testing, and shows that on such a pack of tops there would be nothing either to claim or to allow.

Briefly stated, this means that 19 per cent. of the "dry weight" exactly equals 16 per cent. of the weight at standard condition.

Testing for Water.—When a lot of tops is sent to the conditioning-house, the first operation is to take sufficient tests for moisture to ascertain the average condition of the whole lot. Every bag in the delivery is opened, and lots are extracted from different balls in different parts of the bag. Half-a-pound of sliver is

then weighed accurately on a delicate scale from each lot, and it is then wound on to a wire reel, so that it is exposed on all sides to the air. This reel (A, Fig. 84) is so arranged that it takes the place of one pan of a delicate balance B, whilst it hangs suspended with its load of wool in an oven O, kept at a temperature of 212° or above. At such a heat all the water contained

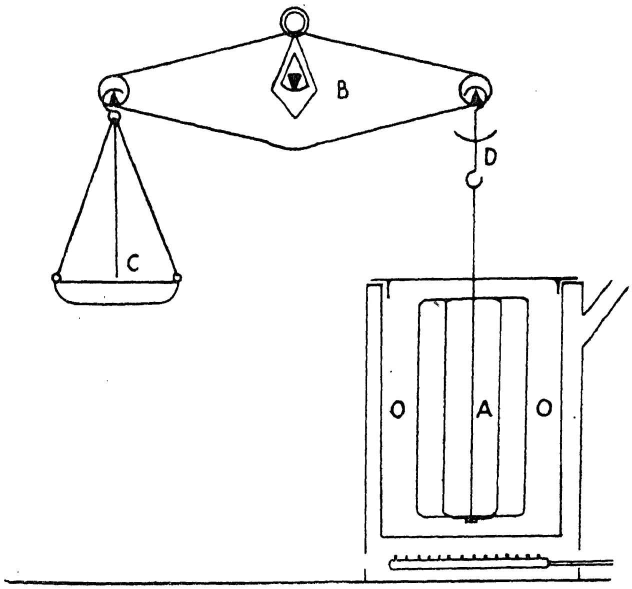

FIG. 84.

in the wool is evaporated in twenty minutes; but the test is usually continued for half-an-hour to ensure that every trace of moisture is removed, when the scale is again balanced carefully. If the sample of top is in standard condition the beam will swing level with $107\frac{1}{2}$ drams in the scale C, as the top will have lost $20\frac{1}{2}$ drams or 16·01 per cent. of the 128 drams in the half-pound put into the oven. In other words, if half-a-pound contains $20\frac{1}{2}$ drams of moisture, one pound

must contain 41 drams or 2 oz. 9 drams. The tests from the four different tops in the same bag may differ considerably. It would be no uncommon thing to find a variation of 2 or even 3 drams between the driest and the dampest top.

The method of using the weights differs from that usually adopted in other balances, for the 8-oz. weight is always left in the scale C, so as to prevent the reel A from ever resting on the hot bottom of the oven; the heat from the numerous gas jets being so great that the lower wraps of wool would inevitably be charred if they were within an inch of the heated iron.

The loss being the important factor in the calculations, it is also much simpler to leave the original weight A in position, so that at the end of the test the scale may be balanced by the addition of sufficient small weights (in a pan on the reel end of the beam D) to replace the weight of the water which has been driven off by the heat.

In places where the testing-machine is kept in constant use it is advisable to have two or three duplicate reels made to weigh exactly the same weight to the decimal of a grain, as well as a duplicate scale beam, as delicate as that in the tester. The reels should always be cool when wool is wound on to them, in order that no moisture may be lost whilst the scale is brought to an accurate balance. The second beam should also be hung a little distance from the oven, where the sliver exposed on the reel will not be affected by the warmth, and in every case the accurate balancing should be done as quickly as possible, for the greater the excess of moisture on a top, the more rapidly will a portion of it evaporate.

It would be impossible to secure an accurate test if wool were weighed on to the reel whilst suspended in

the oven, unless it had been allowed to grow quite cold between two tests. This would involve great loss of time and gas, and if tests were made consecutively, with a single oven, beam, and reel, without allowing either of them to cool, they would make tops appear to be in a better condition than was really the case, by perhaps 1 dram to the pound.

That is to say, a buyer who tested in this manner, and relied on his own calculations, would be losing, or miscalculating, about 1 lb. in every 256 that he bought —roughly, a pound per pack.

From a small lot sent to test, the figures returned by the conditioning-house as showing the correct invoice weight might be—

September 11, 1899.

Delivered by Messrs A. B. & Co.

4 Bags of tops, Lot 1, Gross weight being 1837 lbs.
Declared tare ,, 59 ,,
Nett weight ,, 1778 ,,

	Lbs.	Oz.	Drs.
Eight lots extracted from the above, weighing nett	4	0	0
Result after testing absolutely dry	3	5	12·25
Or loss per lb.	0	2	8·94

Or total dry weight	1494 lbs.	= 84·01%
Regain, 19%	284 ,,	= 15·97%
Correct invoice weight	1778 ,,	= 99·98%
Loss	—	·02%
Original weight	1778 ,,	=100·00%

The above figures are taken from the certificate of a test made by the Bradford conditioning-house some years ago; but as it very seldom happens in practice that the tops are exactly in standard condition, a second illustration is given, in which the same four bags of tops are shown as losing 2 oz. 11½ drams of

moisture, with the consequent amount which the seller must credit to the purchaser.

September 11, 1899.

Delivered by A. B. & Co.

4 Bags of tops, Lot 1, Gross weight being 1837 lbs.
Declared tare ,, 59 ,,
Nett weight ,, 1778 ,,

	Lbs.	Oz.	Drs.
Eight lots extracted from the above, weighing nett	4	0	0
Result after testing absolutely dry .	3	5	2
Or loss per lb.	0	2	$11\frac{1}{2}$

Or total dry weight . .	1476 lbs.	= 83·01
Regain 19% . . .	280 ,,	= 15·76
Correct invoice weight .	1756 ,,	= 98·77
Loss	22 ,,	= 1·23
Original weight . . .	1778 ,,	=100·00

From the first four bags sent to test 8 half-pound samples would be made up, and each of them tested separately. It is probable that the condition in the different balls would vary considerably, so that the figures from the 8 tests might read—

	Lbs.	Oz.	Drs.
1st 8-oz. sample, "bone dry," weighs	0	6	12·50
2nd ,, ,, ,,	0	6	12
3rd ,, ,, ,,	0	6	10·25
4th ,, ,, ,,	0	6	12·50
5th ,, ,, ,,	0	6	10·75
6th ,, ,, ,,	0	6	10
7th ,, ,, ,,	0	6	11·75
8th ,, ,, ,,	0	6	12·50
	3	5	12·25
Total loss, 2 oz. 8·94 drams per lb., or	0	10	3·75
	4	0	0

Testing for Oil.—When conditioning-houses were first established in Yorkshire an attempt was made to fix a standard for the amount of oil to be applied to all tops, at 6 drams to the pound; but as each different class of wool differs in the amount of oil it requires to give it the greatest possible spinning power, this arbitrary standard had to be abandoned, and the custom of testing all lots at the conditioning-house has largely fallen into disuse, because a buyer cannot legally claim on the seller if the tops he has purchased contain more oil than he likes.

His remedy is to test a sample ball to see what oil it contains before he completes the purchase, and if the result be satisfactory he can stipulate that the percentage of oil in the bulk shall not exceed the amount on the sample ball.

We have seen that the amount of moisture in tops from one lot, or even from the same bag, may vary by several drams per lb., because the water is applied in the finishing-boxes, and one set of cans makes only one set of balls; but with oil it is quite different. Oil is applied in the backwashing before both preparing and combing, and it is therefore generally very regular throughout an entire lot because of the enormous number of blendings which take place after the oil is put on to the sliver.

To find the equivalent of doublings in the whole process the number of ends put up in each machine must not be added together, but multiplied by the doublings in each succeeding process, and if the number of ends going up to each box and machine be taken as—

First preparing-box . .	3	ends up
Second	4	,,
Punch-box	4	,,
Comb	18	,,
First finishing-box . .	25	,,
Second ,, ...	3	,,

every end of backwash sliver will have been blended with $3 \times 4 \times 4 \times 18 \times 25 \times 3$ other yards of sliver equally drawn out; and it stands to reason this enormous number of 64,800 doublings will so effectually average any temporary irregularity in the application of oil at the backwashing as to make no material alteration on any one top. It would be an immense advantage if water could be applied at the same stage, but the heat of the comb circles evaporates such a large proportion of the moisture left in the wool by the backwash rollers that the top is far below the natural standard when it reaches the finishing-boxes, and more water must be added in the last process but one to make up the deficiency.

Oil, on the other hand, is not evaporated by heat, and with the exception of a small percentage, which is always absorbed by the noil, all that is put on to the sliver in the backwashing comes right through to the top.

Testing for oil is a very simple process, being little more than a repetition of the process of testing for water. A top must always be tested for water first, and when the absolutely dry weight is ascertained, the sample must be carefully washed in water at 120° F., containing a little good soap in a clean vessel, so arranged that no fibres can escape. After squeezing once or twice it must be rinsed again in clean warm water to remove all traces of soap, and again squeezed. The squeezing-rollers in both cases must be quite clean, so that no extraneous fibres or staples can be picked up by the sliver which is being tested. When squeezed as dry as possible the sliver is again wound on to the reel and suspended on the balance in the oven. As it is now very moist it will take nearly an hour to dry at 212° F., and the scale must be balanced several times, until it is found that all evaporation has ceased and the weight remains quite constant.

When this point is reached, the weights indicating the *total* loss must be noted, and the difference between this weight and the dry weight, previous to washing, will give the exact amount of oil which the sample contained.

This second heating nearly always turns the wool so brown as to make it unfit to blend in again in the carding, and it is customary not to test more than half-a-pound; the resulting figures would therefore be—

	oz.	drs.	
Top in oil	8		
Top in oil, all water dried out . .	6·10	$24\frac{1}{2}$	
Top bone-dry after washing, free from oil and water . . .	6·10	$21\frac{1}{2}$	
Oil in original 8 oz. of top . .	0	3	
Oil per lb.	0	6	or $2\frac{1}{3}$%

It must always be borne in mind that the natural grease or yolk contained within the walls of the wool fibre is soluble in soap and water at high temperatures, and as this yolk must never be mistaken for the applied grease, great care must be taken never to use water above 120° F., or at most 130° F.

In order to obviate the loss of fibre in washing and squeezing, several methods have been invented to remove the oil by the use of ether, or other chemical reagents, in tests of this kind; but as they invariably dissolve part of the natural wool fat as well as the applied oil, the resultant figures are not accurate, generally showing a greater loss of oil than has actually been put on to the wool. For this reason the simple and natural method of washing in warm soap and water is now almost always adopted, and will be found safer and more accurate than the use of volatile liquids which are much more difficult to manipulate as well as being much more expensive.

Comber's Result

64s. Botany Combed by A. Blend 201. 64s. Greasy.

Raw Wool	23,366 lbs.	100·00 per cent.
Top	10,502 ,,	44·94 ,,
Noil	1,060 ,,	4·54 ,,
Waste	3 ,,	0·01 ,,
Shoddy	302 ,,	1·29 ,,
Burrs	48 ,,	0·21 ,,
Evaporation	11,451 ,,	49·01 ,,
	23,366 lbs.	100·00 per cent.

Topmaker's Detailed Calculation of Cost from the Above.

23,366 lbs. raw wool at 35d.	= £3,407 10 10	Top	10,502 lbs. at 6s. 11·34d.	=	£3,643 1 8
10,502 ,, combed ,, 8d.	= 350 1 4	Noil	1,060 ,, 2s.	=	106 0 0
		Waste	3 ,, 2s. 6d.	=	0 7 6
		Shoddy	302 ,, 6d.	=	7 11 0
		Burrs	48 ,, 3d.	=	0 12 0
	£3,757 12 2				£3,757 12 2

The same Calculation with Waste and Shoddy omitted.

23,366 lbs. raw wool at 35d.	= £3,407 10 10	Top	10,502 lbs. at 6s. 11·45d.	=	£3,651 12 2
10,502 ,, combed ,, 8d.	= 350 1 4	Noil	1,060 ,, 2s.	=	106 0 0
	£3,757 12 2				£3,757 12 2

Blend 201. 64s. *Greasy. Combed by A.*

23,366 lbs. raw wool at 35d. . . =	£3,407	10	10	Top .	10,502 lbs. or	44·94%	at 6s. 11·45d. =	£3,651	12	2
10,502 ,, combed ,, 8d. . . =	350	1	4	Noil .	1,060 ,,	4·54%	,, 2s. =	106	0	0
	£3,757	12	2					£3,757	12	2

Tear $9\frac{7}{8}$ to 1.

Blend 201. *Combed by B.*

17,099 lbs. raw wool at 35d. . . =	£2,493	12	1	Top .	7,904 lbs. or	46·23%	at 6s. 8·6d. =	£2,655	5	5
7,904 ,, combing ,, 8d. . . =	263	9	4	Noil .	1,018 ,,	5·95%	,, 2s. =	101	16	0
	£2,757	1	5			52·18%		£2,757	1	5

Tear $7\frac{5}{8}$ to 1.

Blend 201. *Combed by C.*

5,441 lbs. raw wool at 35d. . . =	£793	9	7	Top .	2,381 lbs. or	43·76%	at 6s. 10·6d. =	£819	19	5
2,381 ,, combing ,, 8d. . . =	79	7	4	Noil .	410 ,, }	,, 9·28%	,, { 2s. =	41	0	0
				,, 2nd	95 ,, }		2s. 6d. =	11	17	6
	£872	16	11			53·04%		£872	16	11

Tear $4\frac{5}{8}$ to 1.

Blend 201. *Combed by A.*

After lying in a cellar three months, having gained $2\frac{1}{2}$ *per cent.*

23,366 lbs. raw wool at 35d. . . =	£3,407	10	10	Top .	10,764 lbs. or	46·06%	at 6s. 9·36d. =	£3,649	0	2
10,502 ,, combing ,, 8d. . . =	350	1	4	Noil .	1,086 ,,	4·64%	,, 2s. =	108	12	0
	£3,757	12	2			50·70%		£3,757	12	2

Tear $9\frac{7}{8}$ to 1.

Results and Costs.—It is no exaggeration to say that the success of a commission comber depends entirely on his ability to obtain from every lot of wool he combs a percentage of top which will please his customer the topmaker. To the spinner who buys his own wool and combs it himself the question of yield and tear are of even greater importance; for the commission comber will be very promptly told of his inefficiency, and, after improving his methods, he may obtain new customers. On the other hand, the man who combs only for himself, if he does not compare his work with that of other combers by sending wool out to comb on commission, may keep his own machinery continually employed, but he may at the same time be producing tops at a cost, say, of $\frac{3}{4}$d. a pound more than he could get them produced for from the same wool.

To secure the very best results two points in particular must have very careful attention.

1. The total sinkage caused by the removal of dirt, grease, moisture, and waste in all the processes must be kept as low as possible, that the weight of top and noil resulting may be proportionately high.

2. The yield of top as compared with the amount of noil and waste produced from a given quantity of wool must be forced to the very highest possible point, consistent with perfect freedom from neps and seeds in the finished sliver.

For example, if a maker has a blended pile of good Australian greasy wool ready to comb he may divide it and send it to two combers to see which of them makes the cheapest and most satisfactory top from it. For the sake of illustration we will suppose it is divided into three parts and each part sent to a different firm—a small proportion only being sent to C, because in other trials he had not done as well as B and A. (See p. 229.)

It will be noticed that the comber's returns always include shoddy and burrs and perhaps a little waste, but the prices at which they sell are so low and their quantities are so small that they are often omitted in rough calculations, as they only affect the price of the top by a very small fraction.

Of the three lots here given as illustrations two of them are taken from a lot which was divided between two combers, and the third is added to illustrate the effect of possible differences. In many respects the three results differ widely, and are arranged to show the importance of yield and tear in regard to the price of the top, and the necessity of *both* being good to produce the cheapest top.

In comparing the three results, we find that B has produced much the cheapest top for his customer, and receives in payment 368d. for every 100 lbs. of wool sent to him, because his total yield is very good (though not quite so high as that of C), and, at the same time, his tear is much better than C. This illustrates the advantage of good tear and yield combined, and, on the other hand, A's result shows how useless it is to get good tear without a good total yield, for his top costs the maker 2·85d. more than B's, and he only receives 359·5d. for every 100 lbs. of wool he combs, C only receiving 350d. for every 100 lbs. of wool he combs.

We may fairly conclude that B's top is about in trade standard condition, and that C's is a little too damp, and we also notice that he could not get his top clear at the first operation and has had to recomb it, thereby adding to his own expenses, getting less payment, and increasing the cost to the maker, but turning out a top which will probably look and spin better than any of the others.

A's is evidently in very poor condition, probably 2 or 3 drams below the standard, and when the topmaker sees the result and has the tops tested for moisture, he will refuse to send them out for a month or two, that they may gain the weight or moisture which the comber (to his own loss) has neglected to put into them.

The last calculation shows what the tops cost three months later: they will have gained the excessive amount of $2\frac{1}{2}$ per cent. or nearly 10 lbs. per bag, reducing the real cost of the lot to the topmaker by more than 2d. per lb.; in fact, they now only stand at $\frac{3}{4}$d. more than those combed by C, and showing more clearly than any other figures could do how important it is that the total "yield" should be good, and that the condition should be fully up to trade standard.

1880

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